International Journal of Engineering & Technology, 7 (2.23) (2018) 260-262

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Arsenic and Heavy Metals Contamination of Soils Around Oyu Tolgoi and Tavan Tolgoi Mines, Located in The South Gobi Desert of Mongolia

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Abstract

In this work inductively coupled plasma - mass spectrometry (ICP-MS) method was used to determine content of harmful to human health heavy elements such as As, Cd, Cr, Pb, Th, U, and other essential elements Zn, Cu, Ni in soil samples collected around fence of two largest in Asia copper (Oyu Tolgoi) and coal (Tavan Tolgoi) deposits. The analyses revealed average content of arsenic in the examined soil samples is exceeding 1.4 times the maximum permissible limit. It is consistent with many previous studies emphasizing on a high occurrence of arsenic in soils, well waters of North and Central Mongolia. But the contents of copper in soil samples collected from three leeward locations of the copper mine Oyu Tolgoi are up to 2.18 times higher than the maximum permitted content established by the government standard of Mongolia. The contents of Cd, Ni, Pb, U, and Zn in soil probes collected from leeward locations of Ukhaa Khudag open pit mine of Tavan Tolgoi coal deposit are higher than that of in probes collected from the windward side of that by factor ranging from 1.34 to 1.64. These facts indicate possible transport and spread of heavy elements by wind from these intense operating open pit mines into adjacent dry and windy deserted region of Mongolia.

Keywords: *Gobi desert; heavy metals contamination; wind spread of contaminants of soil*

1. Introduction

Since mining is a major industry in the economy of Mongolia, it is very important to monitor negative influences of mining industry on environment, inhabitant, living creatures and society. In the past decade, mining industry intensively developed in Umnugobi province of Mongolia, where located biggest in Asia Oyu Tolgoi (copper) and Tavan Tolgoi (coal) mines. Thus, investigation of environmental pollution and environmental restoration these mines are vital. The health indicators point to rapid growth of the environmental pollution in this region. Respiratory diseases are among the top ten causes of diseases in the population of Umnugobi province. In 2007, 1148.5 cases of respiratory diseases per 10 000 people were registered, in 2009 it rose to 2188.8 cases per 10 000 people, almost doubled in two years. These figures are 3.5 times the national average statistics of respiratory disease [1]. It is quite reasonable to connect these trends with incredible air, water, and soil man-made pollution by booming mining activity in this region in last decade. For example, measurement of air pollution in Hanbogd village of Umnugobi province in 2012 showed 45 times exceeding of maximum allowable content for coarse particles and 34-35 times that of for fine particles (PM2.5) [2]. Analysis of water quality in Umnugobi province find out 2.5-3.0 times for nickel and 3 times for cadmium exceed of the permissible content limit established by the World Health Organization [3].
In framework of the "Oyu Tolgoi mining project", Updated Assessment of the Impact on the Environment carried out regularly to determine a content of lead, copper, zinc, cadmium, nickel, and iron in soils around of Oyu Tolgoi mining deposit [4]. According to this assessment, the content of copper and lead in soils around of Oyu Tolgoi mining are one level higher than their contents in soils of the capital city Ulaanbaatar and municipal center of Umnugobi province – the Dalanzadgad town.
In 2012 researchers of the soil laboratory of Institute of Geography of Mongolian Academy of Sciences carried out measurement of Cr, Pb, Cd, Ni and Zn content in soils along the road from the "Oyu Tolgoi mining project" area to the "Gashuun Sukhait" Mongolia-China border crossing. The result concluded that the soil in investigated area was not contaminated by heavy metals [5]. There is no public data of any investigation of soil heavy metal contamination for the open pit coal mining at the Tavan Tolgoi deposit.
This work dedicated to the investigation of arsenic and heavy metal contamination of soils in surrounding area of Oyu Tolgoi and Tavan Tolgoi minings.

2. Methodology and results

Soil samples were collected from 20 locations positioned on the outer perimeters of the fences of Oyu Tolgoi mining, and Ukhaa Hudag open pit mine of the Tavan Tolgoi deposit, and from two locations situated in 20 km away from these deposits. Dry and sandy infertile soil samples were gathered from the surface of soil with a small hand shovel. At certain location, around 5 kg of soil were collected from each of four top and center of a 1 meter by 1 meter square of ground surface, and then soils were mixed and

sifted through a 5 mm sieve. Then the sieved soil probe weighing about 0.5 kg was brought out and packed in plastic bags.

Elemental analyses were carried out in Central Geological Laboratory of Mongolia, certified by international standards ISO9001, ISO/IEC17043:2010, and ISO GUIDE 34:200, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Elan 9000) method. The checking analyses of Cd, Cr, Cu, and Pb were performed by atomic absorption spectroscopy (Solaar M5) method at the National University of Mongolia. Table 1 shows contents of arsenic and heavy metals in mg/kg determined by ICP-MS. The average content calculated for each element listed in the Table 1. For comparison, the maximum permissible levels (MPL) of content of As, Cd, Cr, Cu, Ni, Pb, Zn in soil established by Government Standard of Mongolia [6], normal content of uranium in soil [7], and sanitary norm of acceptable concentrations of thorium in soil established in Russia [8] are shown in the last row of the Table 1. The average concentration of arsenic is 1.40 times higher than the MPL. Exclusively, arsenic content in the sample OT1 from northeast of the Oyu Tolgoi mining is higher than MPL by factor of 2.66. In fact, high content of arsenic in water and soils is typical for Central and Northern Mongolia [9,10] so it is hardly to say the observed high content of As is consequence of the nearby open pit mining. Average content of all other analyzed elements, except Cu, however, did not exceed the MPL. As shown in the Table 1, in the samples from three locations marked OT1, OT 2, OT3, the copper concentration exceeded little bit the MPL. The highest concentration of copper was detected in sample OT3 that it was 2.18 times the MPL. These samples were from positions situated in leeward side of the Oyu Tolgoi open pit mine. Figure 1 shows Oyu Tolgoi regional wind mode plotted using monthly data on the average speed and the prevailing wind direction in 2016, provided by the meteorological service of the Umnugobi province. Among the soil samples collected around of the Oyu Tolgoi mining, the sample marked OT9 contained a maximum content of Pb, Th,U and Zn (Table 1).

Table 1: Determined contents of elements of the soil samples gathered from Tavan Tolgoi and Oyu Tolgoi mines. The concentrations of elements are given in mg/kg.

N	Sample name	Element content								
		As	Cd	Cr	Cu	Ni	Pb	Th	U	Zn
1	TT-1	15.16	0.26	71.28	57.11	28.94	19.68	7.34	2.04	92.04
2	TT-2	13.68	0.19	51.38	64.93	23.73	16.77	6.74	1.60	78.43
3	TT-3	<0.5	0.23	71.06	73.85	29.54	17.70	6.15	1.78	90.66
4	TT-4	<0.5	0.18	72.42	87.76	27.20	16.62	6.45	1.64	79.42
5	TT-5	<0.5	0.16	72.27	105.4	25.45	15.40	5.10	1.58	70.30
6	TT-6	10.49	0.16	77.17	45.14	22.43	14.62	5.28	1.51	65.27
7	TT-7	8.60	0.19	79.56	47.17	28.55	17.98	7.01	1.68	77.96
8	TT-8	3.62	0.18	59.55	43.41	23.97	17.03	5.88	1.57	74.51
9	TT-9	11.09	0.19	80.41	670.8	26.36	20.85	6.22	1.78	75.23
10	TT-10	8.43	0.17	59.07	63.27	23.65	16.18	6.45	1.59	70.81
11	TT-11	9.35	0.20	64.82	85.21	29.52	18.46	6.83	1.66	80.79
12	OT-1	15.98	0.14	36.08	102.0	16.40	14.58	6.12	2.59	99.69
13	OT-2	3.20	0.19	44.88	104.0	20.34	17.58	5.96	1.63	69.98
14	OT-3	11.27	0.21	37.19	218.1	17.31	14.78	5.41	1.35	73.55
15	OT-4	8.71	0.19	39.86	43.59	20.25	17.16	5.72	1.37	88.79
16	OT-5	3.67	0.23	47.02	80.44	19.94	18.66	5.65	1.76	84.56
17	OT-6	11.92	0.20	65.78	67.06	35.90	17.09	7.48	1.92	85.11
18	OT-7	9.39	0.18	54.31	50.72	24.81	16.42	6.27	1.71	80.50
19	OT-8	3.59	0.26	52.76	64.88	26.56	19.46	7.35	1.81	88.97
20	OT-9	9.04	0.47	50.39	51.38	26.25	25.56	9.83	2.58	127.5
21	OT-10	12.50	0.44	41.42	37.46	21.10	23.83	8.30	2.44	120.3
22	Demchig	14.12	0.40	58.13	37.67	25.86	25.73	13.89	3.45	140.0
Average value		8.42	0.23	58.49	72.62	24.73	18.28	6.88	1.87	87.02
MPL		6.0	3.0	150.0	100.0	150.0	100.0	6.9	11.7	300.0

It is noteworthy that in the soil sample from the location 20 km far from the Oyu Tolgoi mining, which is near the ancient monastery Demchig, known in Mongolia as the "World energy center", high content of Pb, Th, U and Zn were found, exceeding that of in samples from the vicinity of the Oyu Tolgoi mining. Here the thorium concentration is found two times higher than the MPL established in Russia [8]. A coarse-grained, poor fertile but rich in microelements and heavy metals soils of these places are apparently, indicates a scattering halo of a ore body, located somewhere underneath of surrounding the monastery mountain massive.

In the area of Ukhaa Hudag open pit coal mine of the Tavan Tolgoi deposit, soil samples from ten locations marked by the codes TT1 - TT10 were collected. In these samples the concentration of Cd, Cr, Cu, Ni, Pb, Th, U, Zn do not exceed the MPL. The lowest content of Cd, Ni, Pb, U, Zn was detected in the sample TT6, which is collected from a location in the windward side of the mine. Figure 2 shows Tavan Tolgoi regional wind mode plotted using monthly data of the average speed and the prevailing wind direction for 2016 year. The locations from which samples TT1, TT3, TT4, and TT9 were collected, are situated on the leeward side of the Ukhaa Khudag open pit mine. According to data on the Table 1, in these samples the contents of Cd, Ni, Pb, U, Zn are higher by factors ranging from 1.34 to 1.63 than contents in the sample TT6. The Ukhaa Khudag mining is producing huge amount of soil and coal dust which is might be seen every day from distance kilometers away the mining site. So this content difference can be explained by heavy metal enriched dust transporting and spreading by wind. The contents of arsenic and heavy metals in soil sample TT11 taken from position located 20 km from the Tavan Tolgoi deposit, are close to the corresponding average values presented in the Table 1.

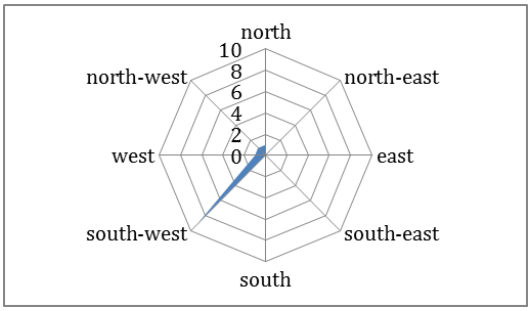

Fig. 2: Wind mode in region of Oyu Tolgoi mine for 2016 year. Wind speed is given in m/s.

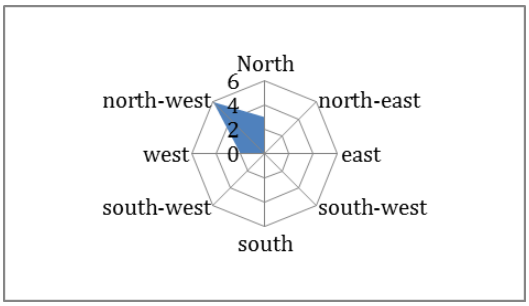

Fig. 3: Wind mode in region of Tavan Tolgoi mine for 2016 year. Wind speed is given in m/s.

3. Conclusion

The atomic absorption and mass-spectrometry elemental analysis of soil samples around of the Oyu Tolgoi copper mining shows MPL exceeding content of arsenic, copper and thorium for some sampling positions leeward respect to open pit mining site position. The difference in concentrations of Cd, Ni, Pb, U, Zn in samples of soil collected from the windward and leeward sides of the open pit mine Ukhaa Khudag of the Tavan Tolgoi coal deposit also indicates a possible transporting and spreading of heavy metals emanating from the open pit coal mining by wind. Therefore systematic, independent, and open to public monitoring of accumulation of heavy metals in soils in surrounding area of both Oyu Tolgoi and Tavan Tolgoi minings is needed.

Acknowledgement

This work has been done within the framework of the project "The investigation of heavy metal contamination of soil on Hanbogd and Tsogttsetsii villages of Umnugobi province, where Oyu Tolgoi and Tavan Tolgoi mines are located" (ARC-2015-14) supported by the Asian Research Center, Mongolia and Korea Foundation for Advanced Studies.

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