HEAVY METALS IN THE ENVIRONMENTAL OBJECTS OF NON-FERROUS INDUSTRIAL REGION OF MONGOLIA, THE TOWN OF ERDENET

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Introduction

Long-term collaboration of the Mongolian and JINR specialists in the field of applying nuclear and related analytical techniques to the environmental studies resulted in a series of joint publications which served the purposes of monitoring heavy metals and radionuclides in different ecosystems of Mongolia. Such cities as Ulaanbaatar, Erdenet and Darkhan are experiencing the ecological stress due to insufficiently well-thought industrial activity of mining and mineral raw materials producing enterprises responsible for more than 70 % gross product in the economy of Mongolia. In 2008 a project «Development of a system of complex monitoring heavy metals and radionuclides in Mongolia based on nuclear and related analytical techniques» was approved for financing by RFBR (Russian Fund for Basic Research) – Mongolia.This project aims at the development of a system of complex monitoring heavy metals and radionuclides in Mongolia to control the state of the environment, to provide rational use of natural resources and to prevent hazardous impacts on human and animals' health of the main anthropogenic sources.

The concept of this project is based on (i) assessment of contamination of the environment with radionuclides over the territories affected by their impact; (ii) investigation of ^{137}Cs distribution in soil and terrestrial vegetation (moss, lichens), as well as of such natural radioactive elements as U, Th, and ^{40}K; (iii) assessment of contamination of the environment with heavy metals of industrially developed areas of Mongolia (Erdenet, Ulaanbaatar). The moss (*Paltegera*) was used to assess the atmospheric deposition patterns of heavy metals and other toxic elements over a large territory affected by non-ferrous industry in the town of Erdenet. Its impact on pasture animals (goats and sheep) was studied through analysis of such inner organs as lung, spleen, liver, kidney, and heart. A total of 37 elemental concentrations in these samples were determined by instrumental neutron activation analysis (INAA) using epithermal neutrons at the IBR-2 reactor, FLNP, JINR, Dubna [1]. The distribution of biogenic elements and heavy metals in water samples were investigated by means of total reflection X-ray fluorescent analysis (TXRF) at Nuclear Research Centre of the National University of Mongolia, Ulaanbaatar [2].

The results obtained evidence for strong accumulation of element-pollutants typical for non-ferrous industry in the town of Erdenet: Cu, Cr, Fe, Ba, *etc*. along with other trace elements and rare earths for the first time determined in these environmental objects.

Study area

Erdenet is the second largest industrial and mining city with 100 thousand populations in Mongolia. Erdenet Mining Corporation is one of the biggest ore mining and ore processing factory in Asia. Erdenet Mining Corporation (EMC or Erdenet) was established in accordance with an agreement between governments of Mongolia and Russian. It started its operation in

1978. The main mineral deposit, extracted by the Corporation was the Erdenetiin-Ovoo area which locates 400 kilometers northwest from Ulaanbaatar, 180 kilometers east from Darkhan city, 60 kilometers northern from Center of Bulgan aimag and 140 kilometers from Russian An ore-processing plant was commissioned in 1981 and Erdenet began exporting copper (30%) and molybdenum (50%) concentrates. Today the Erdenet Mining Corporation (EMC) extracts 25.5 million tons of ores and produces 500 thousand tons of copper and 2 thousand tons of molybdenum concentrates per year. Fig.1 shows a part of the EMC map.

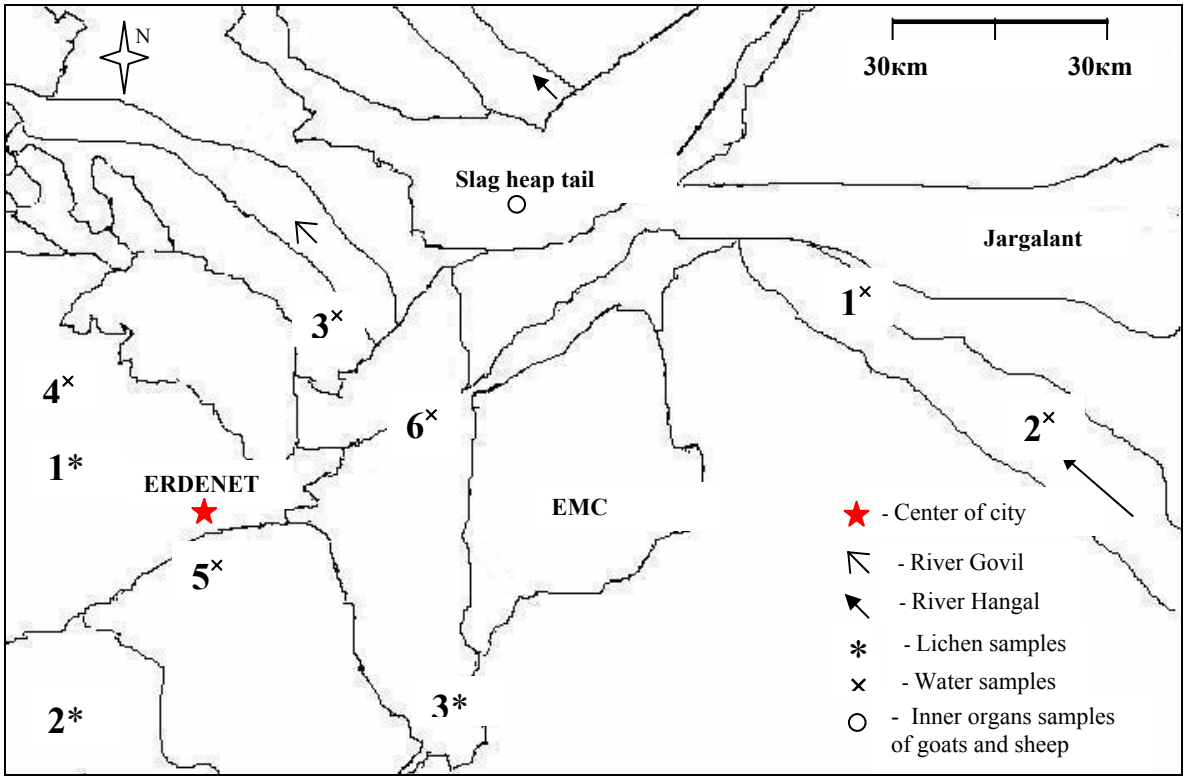

Figure 1. A part of map "ERDENET MINING CORPORATION"

Materials and Methods

Sampling. This study is the first attempt to evaluate levels of atmospheric deposition of heavy metals and some trace elements near industrial and mining city Erdenet, using specific types of lichen biomonitors growing in the arid climate of Mongolia.

The lichens (*Parmelia separata*) were used to study the atmospheric deposition of trace elements. It was shown that the suggested types of lichens could be used as suitable biomonitors to estimate the concentration levels of heavy metals and trace elements in Erdenet atmospheric deposition. Lichen samples collected at sites located 10–15 km from the EMC. The results are compared to the data of atmospheric deposition of Morocco [6] and the clear area of Mongolia [3] (Ulaan taiga).

Monitoring studies of concentration of heavy metals and trace elements in the silts of the Inflow Rivers and soils are important for assessing the effect of contamination by pollutants from industrial, urban and agricultural areas. The samples of silts and soils were collected from the Hangal and Govil Inflow Rivers, which are mainly contaminated by anthropogenic pollutants from industrial, urban and agricultural areas of Mongolia in 2002-2003 years. The samples analysis of heavy metals, minor and trace elements must be useful to

estimate sufficiently the pollution area and river's water. Water samples were collected from rivers near EMC, technological and tap water of the Power plant, the hotel, and drink water from the Shaft of the town Erdenet. Samples of inner organs of 6 pastured animals (goats and sheep) aged 2–7 years were collected from the area (around Erdenet) polluted by thin (~70 micron) white dust of the storage Slag-heap tail veterinary of the municipal units.

Analysis. *Instrumental Neutron activation analysis (INAA)*: INAA using epithermal neutrons at the IBR-2 reactor were performed at the Frank Laboratory of Neutron physics, Joint Institute for Nuclear Research, Dubna [4].

We have determined chemical, toxic elements and some heavy metals in lichen, soil, silt and inner organs samples of around Erdenet by INAA with detection limits within the range of 0.01-10 g/g.

Total reflection X-ray fluorescent analysis (TXRF): TXRF techniques were performed at Nuclear Research Centre of the National University of Mongolia, Ulaanbaatar. We have determined contents of some heavy metals and toxic elements in water samples around Erdenet by total reflection X-Ray Fluorescence techniques [5].

Results

INAA has sensitivity and accuracy for the complex monitoring measurement of heavy metals and trace elements for studying the environmental. Comparison of the results has shown that the mean content of some elements (Mg, Cl, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, As, Sr, Zr, Mo, Ba, Cs, La, Dy, W, Au, Th) in lichen samples collected from the polluted area (Erdenet town) id higher than in lichens from the Morocco area (south-western Africa) and from the clean area (Khubsugul, Ulaan Taiga) Tab.1.

Out of 41 determined elements biogenic or essential macroelements (Na, K, Mg, Ca, Cl) were found; biogenic or essential microelements (Fe, Cu, Zn, Mn, Cr, Se, Co, V, Ti, Ni, As); non-biogenic or other elements (Hg, Sb, Ba, Sr, Cs, Al, Rb, Zr, Nb, Au, Br, Sc, La, Tm, Hf, Ta, W, Th, U and some REE: such as Ce, Nd, Sm, Eu, Tb, Dy) were determined in samples of sediments and soils.

A total of 39 elements were determined in soil and river silt samples from polluted area and river around Erdenet town. Concentrations of some heavy toxic metals in water of river such as Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Sr и Pb exceed the MPMCL accepted in Mongolia Tab.3. The level of Mn content in the technological water (№ 1, 2) from the Power plant and Zn conten in tap water are higher than MPMCL accepted in Mongolia. The results of this study show that water around Erdenet town is polluted by the industrial liquid waste from the Erdenet Mining Corporation.

A total of 35 elements were determined by INAA in the samples of inner organs from goats and sheep inhabiting the area around the storage of slag heap tail in the town of Erdenet.

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Table 1. Concentration of elements in lichen samples (*Paltegera*) from around Erdenet town (in 2005) and Morocco. (mg/kg)

Elements	South-east Bugat No.1.	Southwest Burenbust No.2.	Southwest Burenbust No.5.	North, Bayanundur (Khus) No.1.	North, Bayanundur No.4.	Range of content in Lichens	Mean data of Lichens	**Morocco** [6]	
								k_0-NAA	ED-XRF
Na	6070	2250	1555	1320	598	598-6070	**2358**	639	-
Mg	50400	28500	12000	17900	15400	12000-50400	**24840**		-
Al	23500	8490	4370	5660	4680	4370-23500	**9340**	9150	13100
Cl	308	307	482	152	1070	152-1070	**464**	1220	1180
K	14500	11900	6810	8840	6070	6070-14500	**9624**	5140	6220
Sc	4,0	1,8	1,7	0,96	0,41	0,41-4,0	**1,77**	1.74	-
Ca	7100	7010	11900	5490	17400	5490-11900	**9780**	23200	33600
Cr	15,0	6,4	7,0	3,0	5,8	3,0-15,0	**7,4**	16	-
Ti	2020	741	434	508	521	434-2020	**845**	648	502
V	40,7	13,4	7,46	9,9	8,74	7,46-40,7	**16,0**	37	54
Mn	927	407	170	141	308	141-927	**390**	161	158
Fe	9850	4510	4010	2350	1610	1610-9850	**4466**	5840	4880
Co	6,45	2,50	2,54	1,09	0,64	0,64-6,45	**2,65**	1.84	-
Ni	6,0	2,7	2,0	1,7	1,2	1,2-6,0	**2,72**	-	9.1
Cu	712	142	65,2	53,2	60,7	53,2-712	**206,6**	-	28.6
Zn	42,8	32,4	55,3	46,6	22,9	22,9-46,6	**40**	92.7	84.2
Se	0,32	0,08	0,23	0,03	0,19	0,03-0,32	**0,17**	-	-
As	7,62	3,46	4,29	2,06	2,01	2,01-7,62	**3,9**	2.84	-
Br	4,05	5,64	7,07	5,44	6,14	4,05-7,07	**5,67**	21.8	19.1
Sr	195	155	75,4	81,4	67,4	67,4-195	**114,8**	<29.2	22.8
Rb	37,1	16,4	16,3	11,4	3,89	3,89-37,1	**17,0**	24.3	19.7
Zr	172	98,7	62,4	36,0	43,1	36,0-172	**82,4**	78.0	28.6
Mo	21,6	7,73	6,67	4,30	2,07	2,07-21,6	**8,48**	1.48	-
In	0,014	0,029	0,034	0,022	0,055	0,014-0,055	**0,03**	-	-
I	4,9	7,8	6,1	4,0	7,5	4,0-7,8	**6,0**	-	-
Sb	1,45	0,58	0,54	0,29	0,13	0,13-1,45	**0,6**	0.46	-
Ba	398	216	95	131	134	95-398	**194,8**	47.9	40.4
Cs	2,02	1,05	1,03	0,53	0,20	0,20-2,02	**0,97**	0.52	-
Ta	0,18	0,07	0,07	0,04	0,02	0,02-0,18	**0,07**	-	-
La	12,1	6,43	6,05	3,29	2,02	2,02-12,1	**6,0**	4.8	4.5
Ce	15,7	8,07	8,53	3,91	1,26	1,26-15,7	**7,5**	10.9	9.7
Sm	1,76	0,92	0,88	0,46	0,30	0,30-1,76	**0,8**	0.94	0.94
Lu	1,84	0,90	0,65	0,37	0,18	0,18-1,84	**0,79**	-	-
Gd	55,6	23,9	22,3	10,5	6,64	6,64-55,6	**23,7**	-	-
Tb	0,24	0,11	0,14	0,06	0,04	0,04-0,24	**0,2**	-	-
Dy	2,5	2,0	1,0	0,95	0,91	0,91-2,5	**1,5**	0.77	-
Hf	1,82	0,55	0,54	0,28	0,26	0,26-1,82	**0,7**	-	-
W	0,46	0,16	0,18	0,11	0,08	0,08-0,46	**0,2**	0.11	-
Au	0,044	0,087	0,029	0,084	0,064	0,029-0,087	**0,06**	0.003	-
Th	2,64	1,45	1,36	0,73	0,27	0,27-2,64	**1,3**	1.02	-
U	0,067	0,035	0,032	0,020	0,011	0,011-0,067	**0,03**	0,40	-

Table 2. Concentration of elements in some sediment and soil samples from around Erdenet town in 2005 r. (mg/kg)

Element	River Govil No. 5.	River Hangal No. 9.	River Hangal No. 10.	Soil Jargalant No. 6.	Mean content
Na	18000	28000	22400	14000	20600
Mg	31800	27400	29400	28900	29375
Al	75400	76700	68200	61600	70475
Cl	13.1	5.76	12.1	5,00	9.0
K	20900	23600	21600	19400	21375
Ca	99600	58200	53900	39500	62800
Sc	4.80	9.64	6.85	11,8	8.3
Ti	6510	7610	4260	5550	5982.5
V	143	165	98.6	120	131.6
Cr	32.5	56.1	37.7	58,1	46.1
Mn	900	831	611	839	795.3
Fe	12000	27100	19300	31500	22475
Co	5.90	9.48	8.76	13,0	9.3
Ni	13.5	15.4	13.9	20,7	15.9
Cu	1030	1510	1630	935	1276.3
Zn	24.9	50.0	52.8	82,7	52.6
As	8.3	19.1	16.1	9,5	13.25
Se	0.25	1.23	0.52	0,02	0.51
Br	9.54	4.86	2.68	7,02	6.03
Rb	27.7	51.1	42.9	68,3	47.5
Sr	176	385	351	371	320.7
Zr	111	330	197	312	237.5
Nb	8.01	22.4	14.7	16,7	15.45
Sb	0.414	1.85	2.70	1,18	1.54
Cs	1.51	1.90	1.63	3,58	2.16
Ba	226	452	453	579	427.5
La	31.2	35.6	23.7	30,6	30.3
Ce	42.9	81.1	54.8	97,0	68
Nd	ND	20.1	11.1	21,2	17.5
Sm	7.08	8.17	4.91	7,13	6.82
Eu	ND	0.88	0.37	0,92	0.72
Tb	0.28	0.54	0.38	0,69	0.47
Dy	6.89	6.05	7.21	6,54	6.67
Tm	ND	1.14	0.47	0,77	0.79
Hf	2.43	7.69	4.97	2,43	4.38
Ta	0.34	0.79	0.54	0,96	0.7
W	3.68	5.60	5.46	3,89	4.7
Th	5.11	7.60	5.42	12,50	7.7
U	4.82	5.63	3.64	4,52	4.65

Note: ND - nondetected

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Table 3. Concentration ratio of heavy, toxic elements in some samples from around EMC "ERDENET" and MPMCL in Mongolia (mg/kg)

Elements	Soil Jargalant	MPMCL in soil /Mongolia/ [8]	Soil around Erdenet 1974	Soil /Vonigradov/ [9]	Clark [7]
Pb	-	20	65	10	16
Cd	-	0.9	-	0.5	0.13
Zn	82.7	40	21.6	50	83
As	9.5	5	-	5	1.7
Cu	935	30	95.5	20	47
Mo	-	2	7	2	1.1
Cr	58.1	80	-	200	83
Co	13.0	10	13.3	8	18
Ni	20.1	41	-	40	58
Ba	579	-	-	500	650
V	120	100	-	100	90
Sn	-	2	-	10	2.5
Mn	839	-	230-1150	850	1000
Fe	31500	-	-	38000	-
W	3.89	-	-	-	1.3
Sr	371	-	-	300	340

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