DETERMINATION OF RADIONUCLIDES, TOXIC HEAVY METALS AND TRACE ELEMENTS IN ENVIRONMENTAL SAMPLES

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Key words: *Radionuclide. Toxic heavy metls. Environmental samples. Trace elements. Ger (mongolian national house). Indoor Radon. Solid State Nuclear Track Detector (SSNTD). High Purety Germanium Detector (HP Ge detector). Gamma Spectrometry. Reference Materials. Natural Radioactivity. Dose.* Uranium and Torium Ore. Energy Dispersive Total Reflection X-Ray *Fluorescence Techniques. Ocean Basin. River Basin.*

Abstracts:. The present report outlines the activities in Environmental studies at Nuclear Research Center, National University of Mongolia, Ulaanbaatar. The Nuclear and Related Analytical Techniques, which developed in this center, played on very important role in Environmental studies due to several advantageous features as multielemental, accuracy and low detection limits of these methods. The most appreciated advantageof Gamma Spectrometric, with HP Ge detector and Total Reflection X-Ray Fluorescence Techniques are briefly reviewed and the results on determination toxic heavy metals, trace, natural and man-made radioactive elements in aerosols, soil, water, food and hair samples are discussed in detail. Also, in this report give some results of natural radioactive measurements of soil, building materials and indoor's radon data in Erdenet and Ulaanbaatar cities. In some soil samples of Western Mongolia observed man-made radioisotope Cs-137 14.7-64.8 Bk/kg. It means the Western Mongolia exposed ground and air nuclear explosions at Semipalatinsk (Russia) and Lobnor (China).

1. Radioactivity Analysis and Measurements in Environment

1.1 NATURAL RADIOACTIVE MEASUREMENT

The natural radioactivity and radioactive nuclides are determined using large volume (>100 cm^3), high resolution HP Ge gamma spectrometer in the wide range concentration (0.0002-5.0 %) of uranium and thorium in geological (ore, earth crust, coal, phosphate) and environmental (soil, aerosols and water) samples. The earth crust of Mongolia is rich with uranium and divided into four uranium metallogenic provinces: Mongol-Priargun, Gobi-Tamtsag, Khentei-Daur and Northern Mongolian. Coal samples from the east and south part of Mongolia contain up to 3-10 kg per ton of uranium.

Main population in Mongolia live in ger (national house) and it's structure practically don't accumulate radon. The Indoor radon measurements are needed in side houses and flats, which are made of bricks and concrete. In 1994-96 years we carried out monitoring measurement of indoor radon in 100 flats of Ulaanbaatar and Erdenet using passive differential SSNTD. The concentration range of the radon in these measurements was 12-37 Bq m^{-3} in summer and 40-100 Bq m^{-3} in winter.

1.2. SOME MONGOLIAN BUILDING MATERIALS

The assessment of the radiation dose in humans due to natural sources is of particular importance because the natural radiation is the main contributor to the collective dose of the world's population. The determination of the radioactivity of granite and building materials containing granite is important for the estimation of the enhanced radiation hazard due to the use of granite. The knowledge of the natural level of radioactivity is important to evaluate the gamma-ray exposure contribution from building materials. The main contributors to indoor dose are the members of ^{238}U,^{232}Th decay series and ^{40}K. These radionuclides are widely dispersed in the environment and their concentrations differ significantly from place to other. Radon (^{222}Rn and ^{220}Rn) is produced in the ^{238}U and ^{232}Th decay series and is the product of radium decay. Usually, granites have high and basalt has low radium content and sedimentary and metamorphic rocks have intermediate values. They are the main source of radiation in soils and rocks from which traditional building materials are derived.

EXPERIMENTAL PROCEDURE. In this work, samples were randomly obtained from the local building material suppliers in Ulaanbaatar, Darkhan and Erdenet cities. Samples analyses were made by gamma

spectrometry in order to determine their natural and man-made radioactivity content.

To evaluate the contribution of the radioactivity in the building materials to the natural exposure, simple formulae of the exposure rate and dose limitation were used. Soil samples were collected in order to gain some information about the environment. The natural radioactivity and man-made radioisotopes were measured with a HPGe Coaxil (GC3020-7500SL) detector coupled to an amplifier Mod.2020 and PC Board card S-100 (Canberra) analyzer. Each sample was crushed into powder with a grain size <0.5 mm and then, dried at 105°C for 10-15 hours. Each sample was weighed and sealed in a Marinelli beaker with 1or 2 l volume for about 28 days to give the sample sufficient time to reach equilibrium. Sample masses varied from 700 g to 1500 g in Marinelli beaker.

The gamma spectra were obtained in the 60 keV to 2700 keV energy range for a period of 6000-36000 s. The background correction was accounted for by obtaining a gamma spectrum after replacing the samples with an identical water filled container. The activity of ^{40}K was determined by measuring its 1461 keV gamma rays. The content of ^{226}Ra was determined using the gamma rays of 295.2; 351.9 keV (^{214}Pb) and 609.3, 1764.5 keV (^{214}Bi). The content of ^{228}Ra was determined using the gamma rays 238.6 keV (^{212}Pb); 583.1, 2614.7 keV (^{208}Tl) and 338.7, 911.2 keV (^{228}Ac). The content of U also was measured using the gamma rays 63.3, 92.6 keV (^{234}Th), 143.8, 163.4 keV (^{235}U) and 1001.0 keV (^{234m}Pa). As Certified Reference Materials for the Gamma-Ray Spectrometry Analysis we used uranium ores DH-1, DL-1 (NBL, USA); minerals SARM 3 NIM-L Lujavrite, SARM 1 NIM-G Granite (South African) and Soil-375 (IAEA) samples.

RESULTS AND DISCUSSION. In Table 1-1. shown the natural activity concentration of the samples collected near Darkhan city sites. The activity of the soil samples varies from 24 $Bq.kg^{-1}$, to 40 $Bq.kg^{-1}$ for ^{226}Ra; from 42 $Bq.kg^{-1}$ to 56 $Bq.kg^{-1}$ for ^{228}Ra and from 190 $Bq.kg^{-1}$ to 230 $Bq.kg^{-1}$ for ^{40}K. For the building materials the corresponding ranges: from 12 $Bq.kg^{-1}$ to 68 $Bq.kg^{-1}$ for ^{226}Ra; from 17 $Bq.kg^{-1}$ to 81 $Bq.kg^{-1}$ for ^{228}Ra and from 150 $Bq.kg^{-1}$ to 575 $Bq.kg^{-1}$ for ^{40}K. This indicates that no other materials with more elevated radiation content (such as industrial wastes) were added during manufacturing.

Table 1-1. The natural activity in some building materials of Darkhan city, $Bq.kg^{-1}$.

No	Materials	U (Ra-226)	Th (Ra-228)	K-40.	$C_{Ra\,eq}$
1	Sand coarse	25.0±1.2	20.4±1.5	400±30	85.0
2	Sand, fine	25.0±1.2	20.8±1.5	405±30	85.9
3	Crushed stone	12.3±1.0	28.1±1.2	472±20	88.8
4	River gravel	22.2±1.5	24.0±1.2	462±20	92.1

5	Cement (Darkhan)	18.5±1.3	40.6±1.5	391±30	106.6
6	Lightweight aggregate, coarse	68±2.0	81±2.1	661±18	234.7
7	Lightweight aggregate, fine	64±2.0	77±2.1	575±19	218.4
8	Dolomite powder, white	21±1.2	17±1.2	347±25	72.0
9	Wooden saw-dust	< 12	< 20	150±12	< 52
10	Soil No.1	36±1.8	42±1.5	220±20	113.0
11	Soil No.2	40±2.5	49±1.1	230±20	127.8
12	Soil No.3	24±1.2	56±1.5	190±18	118.7
13	granite	320±10	249±15	337±15	702

Table 1-2 shows the range of the activity concentration measured in building materials from Mongolia and other countries. These values are arithmetic mean of the content measured in different materials. The building materials from North of Mongolia showed the background and intermediate contents of ^{226}Ra and ^{228}Ra lower than those of other places.

Table 1-2. Range of the mean radionuclides content ($Bq.kg^{-1}$) in building materials.

Place	$^{238}U^{*}$	$^{232}Th^{*}$	^{40}K
Mongolia (Darkhan)	12-68	17-81	150-661
Mongolia granite	120-350	150-250	200-350

Note: * -Assuming ^{238}U-^{226}Ra and ^{232}Th-^{228}Ra are in equilibrium.

The radioactivity concentration of building materials can be compared using their radium equivalent activities. The radioactive equilibrium in the uranium and in the thorium series cannot be assured without further measurements, the precursors of ^{226}Ra and ^{228}Ra emit weakly penetrating radiation. The concentration of ^{238}U and ^{232}Th can, therefore, be replaced by the ^{226}Ra and ^{228}Ra concentrations, respectively, to estimate the exposure rate, radium equivalent and hazard indices. For these samples, $C_{Ra\ eq}$ varied from 78.4 $Bq.kg^{-1}$ (sand) to 232.6 $Bq.kg^{-1}$ (aggregate); 702 (granite) and 123.2 $Bq.kg^{-1}$ for soil. Table 1-3 shows the measured dose rate using dosimeters on the surface of the building materials' products in Darkhan. The gamma dose rate varied from 0.09 $\mu Sv.h^{-1}$ (metals wire) to 0.27$\mu Sv.h^{-1}$ (lightweight aggregate); 0.36 $\mu Sv.h^{-1}$ (granite) and 0.16 $\mu Sv.h^{-1}$ for soil. The external hazard index varied from 0.21 (sand) to 0.63 (aggregate) and 0.32 for soil. The internal hazard index varied from 0.26 (sand) to 0.81 (aggregate) and 0.40 for soil. The hazard indices are always lower than unit value. The arithmetic mean of the activity concentration and the corresponding radium equivalent activity, absorbed gamma dose rate and hazard indices are shown in Table 1-5, for each

type of material. It can be seen that, on the average, the exposure due to local building materials is greater or approximately equal to that due to local soil. These results indicate that such materials are not the major source of exposure. Taking into account that in Mongolia (Darkhan, Erdenet, Ulaanbaatar cities) the temperature usually ranges from -35°C (too long winter approximately 6 months) to +35°C (summer) and the buildings are ussually not ventilated. This means that, one needs to ventilate houses regularly in winter, to reduce the indoor radon concentration.

Table 1-3. Dose rate range of building materials and products of Darkhan.

Materials	Mean activity concentration, Bq kg^{-1}			$C_{Ra\,eq}$ Bq/kg	D μSv/h	Hazard indices Ext Int
	^{238}U	^{232}Th	^{40}K			
Roof tile	40.0	56.0	430	153.2	0.11-0.16	0.41 0.52
Concrete block	38.0	64.0	412	161.2	0.13-0.20	0.43 0.54
Concrete products	44.6	54.0	395	152.2	0.10-0.24	0.41 0.53
Aggregate	66.0	81.0	660	232.6	0.16-0.27	0.63 0.81
Sand	18 - 20	20	400	78.4	0.16	0.21 0.26
Cement	15 –22	40	391	105.8	0.15	0.28 0.33
Granite	120-350	200-250	340	702	0.28-0.36	0.47 0.80
Soil	24 – 40	42 – 56	210	123.2	0.16	0.32 0.40

1-3. DETERMINATION OF U, Th AND Ra/U RATIO

A comparative HP Ge detector's gamma spectrometry method to determine Uranium, Thorium contents and Ra/U ratio was used. Uranium Standard 12 Reference Materials with Uranium contents from 0.0041 to 4.04 % were employed. The working calibration curve has been established to determine the Uranium contents with an accuracy of 2-8 % depending on the contents of Uranium in the samples. Standard 4 Reference Materials with the known thorium contents from 0.007 to 0.1 % for the determination of thorium contents were used. Also a simple comparative method for the determination of Radium and Uranium ratio was proposed. This method is based on the measurements of gamma rays intensities with the energies of 143.7 and 186.6 (185.7+186.2) keV for Uranium Standard Reference Materials in which the Ra/U equilibrium is known. These method for the determination of Uranium, Thorium and Ra/U ratio was tested on numerous samples and compared with chemical analysis results (Table 1-4). Q/A (Q/C) was tested (Table 1-5).

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Table 1-4. The results of Uranium Ore samples analysis. (Sandstop Uranium mining of Kharaat, Middle Gobi, Mongolia

Samples code	Uranium, %		Thorium, ppm		Ra/U x 1E-7	
	γ-spectrometry	other methods	γ-spectrometry	other methods	γ-spect.	chemic.
7G-1	0.015±0.005	0.015	45·5	50	3.0 3.4	
7G-2	0.006±0.002	0.006	12·2	10	2.8 2.5	
7G-3	0.015·0.005	0.018	36·3	40	2.5 2.7	
7G-5	0.071·0.008	0.076	68·4	70	3.7 3.6	
7G-6	0.023·0 006	0 024	17 2	20	3.9 3.8	
7G-8	0 092·0.010	0.089	48·5	50	3.4 3.9	
7G-9	0.010·0.002	0.010	21·3	20	4.0 3.8	
7G-10	0.018·0.002	0.020	<10	10	3.7 3.7	
7G-15	0.247·0.009	0.252	112·7	120	5.4 5.2	
7G-23	0.013·0.005	0.007	23·3	20	7.7	7.5
7G-26	0.024·0.006	0.020	22·3	20	3.5	3.3
11G-5	0.118·0.011	0.122	68·4	70	3.8	4.0
11G-9	0.027·0.006	0.029	34·4	30	8 2	7 9
11G-10	0.008·0.003	0.011	<10 10		6.9	7.0
11G-13	0.229·0.008	0.239	28·3	30	3.1	3.4

Table 1-5. QA (QC) results of Uranium Ore Reference Materials analysis.

Reference Materials	Uranium, % γ-spectrometry I other methods		Ra/U x 1E-7 γ-spectrometry
ACP77-22 USA	0.108-0.007	(0.094-0.114)	3.07·0.47
ACP78-21 USA	0.060:0.008	(0.054-0.065)	7.91·0.93
ACP83-11 USA	0.387·0 007	(0.347-0.414)	3.41·0.28
ACP84-13 USA	0.132·0.005	(0.114-0.146)	3.14·0.40

1.4. MAN-MADE RADIONUCLIDES IN ENVIRONMENT

Determination of ^{137}Cs and ^{90}Sr in soils is of great importance owing to the fact that plant roots are one of the ways of incorporation into human organisms and other verifiabrates from both food and water. ^{137}Cs and ^{90}Sr are two of the fission products released into the atmosphere as a result of nuclear tests carried out since 1945, accidents of nuclear facilities and, due to their long half-lives are considered the major contributors to the overall collective dose from artificial radiation. The activity of ^{137}Cs is easily obtained using gamma spectrometry. Some samples of the soil from Western Mongolia obtain ^{137}Cs, the activity range was 14.7-64.8 Bq/kg. In soil samples from central territory of Mongolia don't show traces of this isotope. It means, Western Mongolia was exposed to air and ground nuclear explosions at Semipalatinsk (Russia) and Lobnuur (China). This region needs more careful study of radioactive nuclides analysis and radioactivity dose measurements.

Radioactivity levels in foodstuff are usually very low. Therefore, bulk samples are preferable (10 ltrs. 5 kg). Good statistics could be achieved if the sample counts (S) in the counting time (T) is 3 times larger than the standard deviation of the background: S>3SQRT(B). Minimum detectable limits (MDL) from B, T, W and E can be defined and the weight of samples can be calculated from .MDL,. The maximum. acceptable concentration (MAC) or ^{137}Cs isotope's activity in Foodstuff is 40 Bq/kg. Then the desired MDL equally 0.4 Bq/kg (usually set as 1 % of MAC). MDL=0.4 Bq/kg at B=3600 counts. If the efficiency of the detector E=0.12; measurement time T=6000 s. a weight of sample calculated as 625 g.

Each sample was crushed into powder with a grain size <0.5 mm and, then dried at 105°C for 10-15 hours. Each sample was weighed and sealed in a Marinelli beaker with 1000 or 2000 ml of sample. A sample weight varied from 700 g to 1500 g in Marinelli beaker. In some samples of Georgian green tea ^{137}Cs was obtained with the activity up to 85 Bq/kg. Also in the samples of fruit jam supplied from Germany 75 Bq/kg-^{137}Cs was obtained. At present time we only determined Cs-137 and Cs-134. We need future analysis of the alpha and beta emitter nuclides in environmental samples.

2. Toxic Heavy Metals and Trace Elements Analysis in Environment

The surface water resources in Mongolia are about 34.5 cubic kilometre per year. Most of the rivers originate from one of the three largest mountain areas and there are no perennial rivers in the Gobi. The rivers in Mongolia are divided into three main basins, depending on its drainage: Arctic Ocean Basin (AOB), Pacific Ocean Basin (POB) and Internal Drainage Basin (IDB) of Central Asia. Consequently, the rivers in Mongolia are of mountainous origin. Therefore, its upland watershed is small and relatively isolated, stream flows are low with the steep slopes of the stream bed, causing relatively high velocities, and bottom scour removes silt and clay, leaving rocks, gravel and sand. The water of the rivers is cool and clear. Most of the rivers, specially in rural areas are not yet affected by human activities and main rivers have received neither discharge from municipal or industrial waste waters. The toxic heavy metals and trace elements monitoring studies began from 1997 in Nuclear Research Center, National University of Mongolia to evaluate the contamination level..

The purpose of this paper is to estimate the level of waste and provide information about the distribution of toxic heavy metals and trace elements along Tuul river near Ulaanbaatar and of Selenga river basin.

2.1 Toxic heavy metals and trace elements along Tuul river near Ulaanbaatar

The river Tuul is one of AOB and for a case study of the Environmental contamination, it is one of the most interesting areas in Mongolia, because it flows from east to west around Ulaanbaatar, the only urbanized industrial city in the country. The samples were collected from 14 points along the Tuul river near Ulaanbaatar and the trace elements and toxic heavy metals of water samples are analyzed by Energy Dispersive Total Reflection X-ray Fluorescence Technique (ED-TRXRF). The technique consist of the Mo-anode tube exiting system with operating conditions of 45 kV and 10-20 mA of type ID-3000 SEIFERT (Germany), the X-ray spectrometer with Si(Li) detector of CANBERRA (USA) and a Total Reflection Attachment of Atominstitut Vienna, Austria. The ED-TRXRF Technique is one of high sensitivity multielemental analytical technique for liquid samples. Some results of these sample analyses are given in Table 2-1. The determined chemical elements in the river water can be considered in 3 groups as: the macroelements (P, S, Cl, K and Ca); iron's group (Fe, Ti, V, Cr, Mn, Co and Ni) and copper's group (Cu, Zn, W, Hg, Pb and U).The determination of trace elements in water is one of the important parameters of water quality. With the exception of Cr, Cu and Zn, the levels of trace elements and toxic heavy metals in these water samples are lower than MPC (maximum permissible concentration). Other

elements P, S, Cl, K and Ca contents are lower than MPC. But the contents of Fe are 0.3 and 5 ppm. In some sample of water the content of Co is 18 times higher than MPC. The content of Cr, Mn and Pb elements in few times higher than MPC. The results (Table 2-1.) of analysis of some samples show that they can not be used as drinking water. The trace elements and toxic heavy metals as As, Ba, Cd, V, Se, Ag and Hg were not observed.

Table 2-1. Toxic heavy metals and chemical elements in water of Tuul river.

Sampling places	S	Cl	K	Ca	Cr	Mn	Fe	Ni	Cu	Zn	Br	Sr	Pb	U
	PPm				PPb									
1. Soldier's Town	33	10	3	19	241	53	864	74	75	91	111	169	163	143
2. Ubulan, tuul river	25	8	2	16	277	38	968	92	47	92	20	133	206	104
3. Gatsuurtai	68	24	3	17	458	60	2214	138	138	185	166	209	290	328
4. Bayan zurkh bridge	44	23	3	25	351	61	1740	71	67	61	55	189	165	231
5. Ikhtenger bridge	35	17	3	18	380	93	1645	118	196	153	70	175	325	81
6. Zaisan	89	92	13	74	402	131	1526	97	72	130	1185	684	292	338
7. Sonsgolon bridge	91	85	2	22	661	192	1806	147	124	112	111	209	360	985
8. Befor W W Refining	240	365	8	112	229	118	1611	117	144	178	518	1543	108	235
9. After W W Refining	56	27	6	28	343	87	2704	108	70	262	144	246	152	86
10. Yarmag	25	10	2	18	231	65	1190	84	57	79	45	180	166	61
11. Biofactory	68	35	4	26	301	49	5068	185	115	185	57	219	349	127
12. Songinokhai rkhan	40	27	4	29	317	110	1696	116	60	176	148	206	328	123
13. Cliff	65	49	3	23	286	30	2018	180	149	191	647	261	199	92
14. Poultry farm	74	24	4	31	358	39	1532	111	72	115	90	273	157	76

2.2 Distribution of toxic heavy metals and trace elements of Selenga river basin

Main inflow of the Lake Baikal – Selenga river belongs AOB in Mongolia and the distribution of toxic heavy metals and trace elements in the water was studied since 1997 and the results of the monitoring studies are given in

Table 2-2. 2-3, 2-4 and 2-5. Sampling location of Selenga river basin can be divided into 4 zones: first - the lake Xybsygyl and Egiin river; second-from upper part Orkhon river to Nart somona; third-from upper part Selenga river with inflowing rivers Ider, Delgermuren, Chuluut and lake Terkhiin-tsagaan and fourth-rivers Tuul, Kharaa, Eroo, down part of Orkhon and Selenga rivers. The water of the fourth zone is more affected by human activities and received main discharge from municipal or industrial waste water. More wasted location of down side Tuul river rom Ulaanbaatar, down part Kharaa river from Darkhan and down part Selenga river from Sukhbaatar. It means, that the regular monitoring study in this fourth zone is needed to be carried out from time to time.

Conclusions

This report is intended to summarize the results of last year studies of radioactivity and radionuclide analysis and determination of toxic heavy metals and trace elements in environment of Mongolia. The data provides some of the background information necessary to the understanding of the values obtained. With the continuing expansion of world's nuclear programs and increasing of urbanization and industry in Mongolia one must expect a variety of radionuclides and trace, toxic elements released into the environment.

Table 2-2. Contents of elements in water of Khybsygyl lake, Egiin river and middle part of Selenga river. (Zone 1, sampling places 8, 8-a, 9, 6, 5).

Elements	Sampling places				
	8	8a	9	6	5
P. ppm	25	20	21	8	10
S	48	23	36	32	18
Cl	47	29	43	10	11
K	6	3	4	4	3
Ca	63	52	71	39	40
Ti . ppb	169	177	178	145	171
V	91	86	158	64	85
Cr	165	161	150	145	140
Mn	82	75	85	63	56
Fe	1012	1076	1254	1215	1241
Co	65	63	134	43	54
Ni	57	76	75	60	63
Cu	48	55	104	35	42
Zn	80	47	74	70	82
W	183	139	187	396	107
Pb	80	52	147	53	57
Th	168	162	360	147	112
U	200	222	404	227	155

Table 2-3. Contents of elements in water Ider and other inflow rivers upper part Selenga river. (Zone 2, Sampling places 10, 10-a. 11).

Elements	Sampling places 10	10a	11
P. ppm	21	19	10
S	59	45	18
Cl	16	33	13
K	8	3	2
Ca	39	37	26
Ti . ppb	193	179	135
V	140	86	96
Cr	137	174	159
Mn	73	78	66
Fe	834	1094	630
Co	107	71	55
Ni	83	63	58
Cu	72	91	294
Zn	122	143	62
W	134	141	107
Pb	47	98	73
Th	236	158	165
U	322	203	191

Table 2-4. Contents of elements in water of South Tamir and upper part Orkhon rivers. (Zone 3, Sampling places 12, 13, 7).

Elements	Sampling places 12	13	7
P. ppm	18	13	11
S	33	22	34
Cl	10	13	26
K	2	4	5
Ca	14	27	40
Ti . ppb	128	163	178
V	156	99	95
Cr	181	130	241
Mn	59	60	67
Fe	882	744	1067
Co	98	53	62
Ni	47	64	59
Cu	134	50	237
Zn	112	115	139
W	104	104	84
Pb	79	81	59
Th	260	151	187
U	323	205	223

Table 2-5. Contents of elements in water Tuul, Kharaa, Eroo rivers, down side of Orkhon and Selenga rivers. (Zone 4, Sampling places 1, 2, 14, 4, 3, 17, 15, 16).

Elements	Sampling places							
	1	2	14	4	3	17	15	16
P. ppm	11	10	11	8	13	8	21	12
S	16	16	55	54	61	12	38	35
Cl	5	11	17	34	36	5	30	15
K	2	4	4	4	5	2	4	4
Ca	14	20	31	44	54	15	47	46
Ti . ppb	219	226	141	144	814	81	153	126
V	98	95	82	34	109	75	121	68
Cr	236	303	195	208	200	186	196	98
Mn	80	133	76	124	359	48	71	50
Fe	380	3234	1478	1335	9414	1988	1204	814
Co	62	67	59	27	80	33	62	51
Ni	56	158	120	147	255	143	161	88
Cu	58	51	227	54	46	29	57	40
Zn	126	123	117	184	572	168	110	72
W	132	110	179	60	97	87	121	107
Pb	166	146	234	105	155	149	190	169
Th	88	96	161	86	98	111	224	113
U	201	173	157	147	157	149	227	137

Товч утга: МУИС-ийн Цөмийн судалгааны төвд хүрээлэн байгаа орчны талаар хийгдсэнсудалгааны дүнгээр энэхүү илтгэл хийгдсэн. Тус төвд хөгжүүлэн буй болгосон цөмийн физикийн шинжилгээний арга зүй, техникүүд өнөөдөр хүрээлэн байгаа орчны судалгаанд чухал үүрэгтэй, нарийвчлал, мэдрэх чадвар багатай, олон элементийг нэгэн зэрэг тодорхойлдог чанараараа давуутай юм. Гамма болон бүрэн ойлтын РФА спектрометрийн аргаар агаар, хөрс, ус, хүнс болон үс зэрэг дээжинд байгалийн, хүний үйл ажиллагаагаар хийгдсэн цацраг идэвхит, химийнзарим элементүүд, хортой хүнд металл тодорхойлсон дүнг өгүүлсэн. Мөн хөрс, барилгийн материалын цацраг идэвхи, орон байрны радоны хэмжилтийн болон баруун монголын зарим хөрсний дээжинд цацрагт цөм Cs-137 нь 14.7-64.8 Бк/кг хүртэл хэмжээтэй илэрсэн. Энэ нь Орос улсын Семиплатанск, хятадын улсын Лобнуурын туршилтын талбайд удаа дараа цөмийн зэвсэг туршсантай холбоотой баруун монголын газар нутаг бохирдсоныг харуулж байна.