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G. Ganbold\*, Sh. Gerbish, M. V. Frontasyeva, S. S. Pavlov,  
T. M. Ostrovnaya, N. Baljinnyam

ASSESSMENT OF HAZARDOUS IMPACT  
ON THE PASTURED ANIMALS OF NON-FERROUS  
INDUSTRY IN THE TOWN OF ERDENET, MONGOLIA

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\*Nuclear Research Center, National University of Mongolia, Ulan-Bator,  
Mongolia

Ганболд Г. и др.

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Оценка вредного воздействия на пастбищных животных горно-обогатительного комбината (ГОК) г. Эрдэнэт (Монголия)

Впервые для оценки загрязнения окружающей среды горно-обогатительным комбинатом (ГОК) г. Эрдэнэт (Монголия) проведены исследования с использованием биомониторов и метода ИНАА на реакторе ИБР-2. Для определения вредного воздействия отвального хвоста и открытого карьера ГОК выбраны некоторые внутренние органы (легкие, селезенка, печень, почка и сердце) в качестве биомониторов у пастбищных животных с прилегающих территорий. Метод ИНАА с использованием тепловых и резонансных нейтронов позволил определить концентрации более 37 элементов в образцах внутренних органов пастбищных животных (козы и овцы). В результате изучения данных образцов показано, что выбранные внутренние органы могут быть использованы для оценки вредного воздействия горно-обогатительного комбината г. Эрдэнэт на окружающую среду. Проведено сравнение полученных результатов с литературными данными.

Работа выполнена в Лаборатории нейтронной физики им. И. М. Франка ОИЯИ, Дубна, и Центре ядерных исследований Монгольского государственного университета, Улан-Батор.

Сообщение Объединенного института ядерных исследований. Дубна, 2006

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Assessment of Hazardous Impact on the Pastured Animals of Non-Ferrous Industry in the Town of Erdenet, Mongolia

The level of hazardous impact of heavy metals and trace elements on the pastured animals (goats and sheep) was evaluated by biomonitoring techniques using inner organs (such as lung, spleen, liver, kidney, heart). The concentration of 37 elements was determined by INAA. Uptake abilities of lung, spleen, liver, kidney and heart were compared for these heavy metals and trace elements. The content of heavy metals and other trace elements in these samples was determined by instrumental neutron activation analysis using epithermal neutrons (ENAA) at the IBR-2 reactor, FLNP JINR, Dubna. The obtained results were compared with the reference materials data.

The investigation has been performed at the Frank Laboratory of Neutron Physics JINR, Dubna, and Nuclear Research Center of National University of Mongolia, Ulan-Bator.

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## INTRODUCTION

Erdenet is the second largest industrial and mining city with 100 thousand population in Mongolia. 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 t of ores and produces 500 thousand t of copper and 2 thousand t of molybdenum concentrates per year.

### 1. EXPERIMENTAL PROCEDURE

Monitoring studies of concentrations of heavy metals and trace elements in animal inner organs (such as lung, spleen, liver, kidney and heart) are important for assessing the effect of contamination on animal health and safety of products of animal origin in human nutrition. The purpose of this study has been to evaluate the levels of some heavy metals and trace elements in inner organs of goats and sheep from the industrial and mining region of Erdenet.

**1.1. The Study Area.** Figure 1 shows a part of the EMC map. The main pollution sources of heavy metals and trace elements in the EMC environment are the white dust from the storage of Slag-heap tail (Fig. 2, *a, b*); ores [1] of the open-pit mine and the storage of nonstandard ores, rocks and rubbish (Fig. 3). Now about 25 million t of tail's pulp is thrown out by 20 km double pipes per every year to the storage of Slag-heap tail. Some factors of metal enrichment of tail and ores are given in Table 1.

**1.2. Sampling, Collection and Preparation of Samples.** Samples of inner organs of 6 pastured animals (goats and sheep) aged 2–7 years were collected from the area polluted by thin (~ 70 micron) white dust of the storage Slag-heap tail (Fig. 4) veterinary of the municipal units. Wet inner organs were burnt in the ash-box in the central state laboratory of Mongolian veterinary, Ulan-Bator. The temperature was slowly increased up to 105°C during 1.5 h. At 105°C it was burning for 4 h and in the end the temperature was slowly decreased from 105°C to 0°C during 1.5 h.

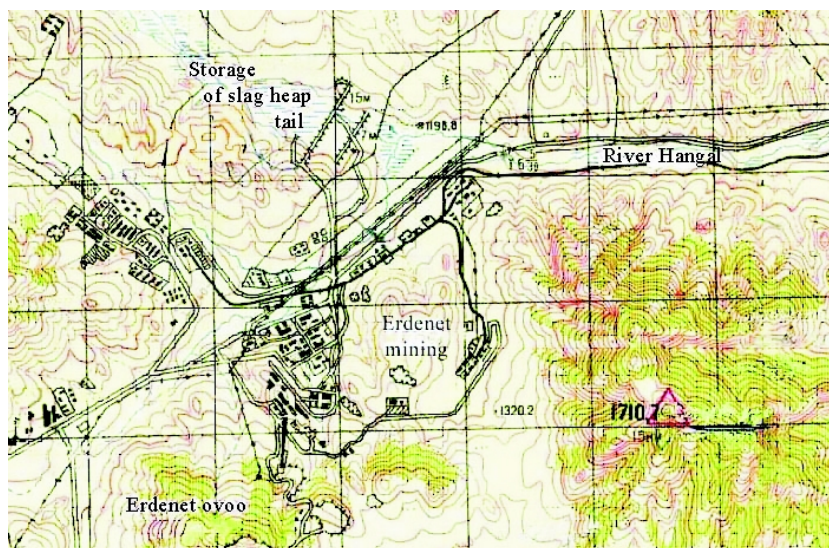


Fig. 1. A part of map «ERDENET MINING CORPORATION»

**Table 1. Some metal's content in the Cu–Mo ore and tail of the ERDENET enterprise**

Element	Average content in the crust, % [2]	Average content in the Cu–Mo ore, % [1]	EF in the Cu–Mo ore	Average content in the tail, % [1]	EF in the heap tail
Cu	0.0047	0.82	288	0.128	45.4
Mo	0.0011	0.019	28	0.0083	12.6
As	0.0005	0.0215	71	0.0048	16
Sb	0.00005	0.0025	82	0.0007	233
Cr	0.0083	0.0022	0.4	0.0081	1.6
Fe	5.0	3.03	1	3.0	1
Co	0.002	0.0016	1.3	0.0025	2.08
Zn	0.0083	0.011	2.2	0.0075	1.5
Ce	0.0046	0.0053	1.9	0.0036	1.3
W	0.00014	0.0027	31.8	0.0009	10.7
Pb	0.0016	0.0089	9.2	0.0079	8.2

Note: EF — enrichment factor.  $EF = [C_X/C_{Fe}] : [C_{Bg}/C_{Fe}]$ .



Fig. 2. The double pipe of tail's pulp to the storage of Slag-heap tail (a); white sand or dust of the storage of Slag-heap tail (b)

**1.3. Analysis (Instrumental Neutron Activation Analysis).** The ash samples of the inner organs were analyzed at the IBR-2 reactor of FLNP JINR, Dubna, using thermal and epithermal neutrons. Most elements were determined by ENAA with detection limits within the range of 0.01–10 g/g. The samples were irradiated in channels of the fast pulsed IBR-2 reactor, the flux parameters of neutrons at irradiation channels: the thermal neutron flux density of  $1.1 \cdot 10^{12} \text{ cm}^{-2} \cdot \text{s}^{-1}$  and fast neutron density of  $1.4 \cdot 10^{12} \text{ cm}^{-2} \cdot \text{s}^{-1}$ . For the neutron flux density measurement, the gold foil was used [3]. Two kinds of analysis were performed: the long irradiation (for 100 h) in channel (Ch. 1) was used to determine the elements associated with long-lived radio-nuclides (As, Cd, Ba, Br, Ce, Cs, Eu, Fe, Ni, La, Rb, Sb, Sc, Se, Sm, Th, U, Zn) and the short irradiation (for 20 min) in channel (Ch. 2) was used for short-lived radio-nuclides (Al, Ca, Cl, I, K, Na, Mg, Mn, V, Cu).

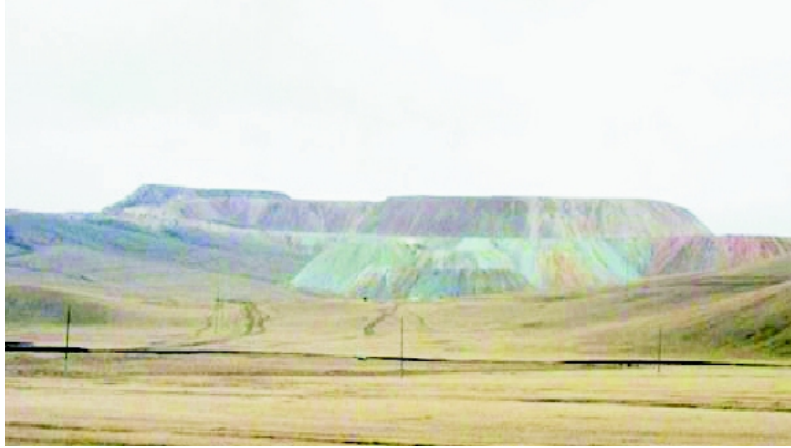


Fig. 3. The storage of nonstandard ores, rocks and rubbish from the open-pit mine



Fig. 4. Pasture animals (sheep and goats) around the Slag-heap tail storage

Gamma-ray spectra were recorded 4–5 times using the gamma spectrometers with HP Ge detector. Cooling times of 5 and 10 min were chosen after the decay periods following the short irradiation and those of 5, 13, and 20 d for the long irradiation.

## 2. DISCUSSION AND CONCLUSION

Out of 37 determined elements biogenic or essential macroelements (Na, K, Mg, Ca, Cl) were found; biogenic or essential microelements (Fe, Cu, Zn, Mn,

Cr, Se, Mo, I, Co, V, Ni, As), non-biogenic or other elements (Hg, Sb, Ba, Sr, Cs, Al, Rb, Ag, Au, Br, Sc, Co, In, La, W, Ta, Th, U and some REE: such as Sm, Eu, Tb) were determined by INAA and shown in Tables 2–7. Mean data of elemental contents are given in Table 8 and the distribution of elements in inner organs are shown in Fig. 5. Results of comparison of mean contents for some elements of inner organs with the ground animal data and ratio of contents Na and K (from 0.20:1 to 0.59:1) in inner organs of sheep and goats are shown in Tables 9 and 10.

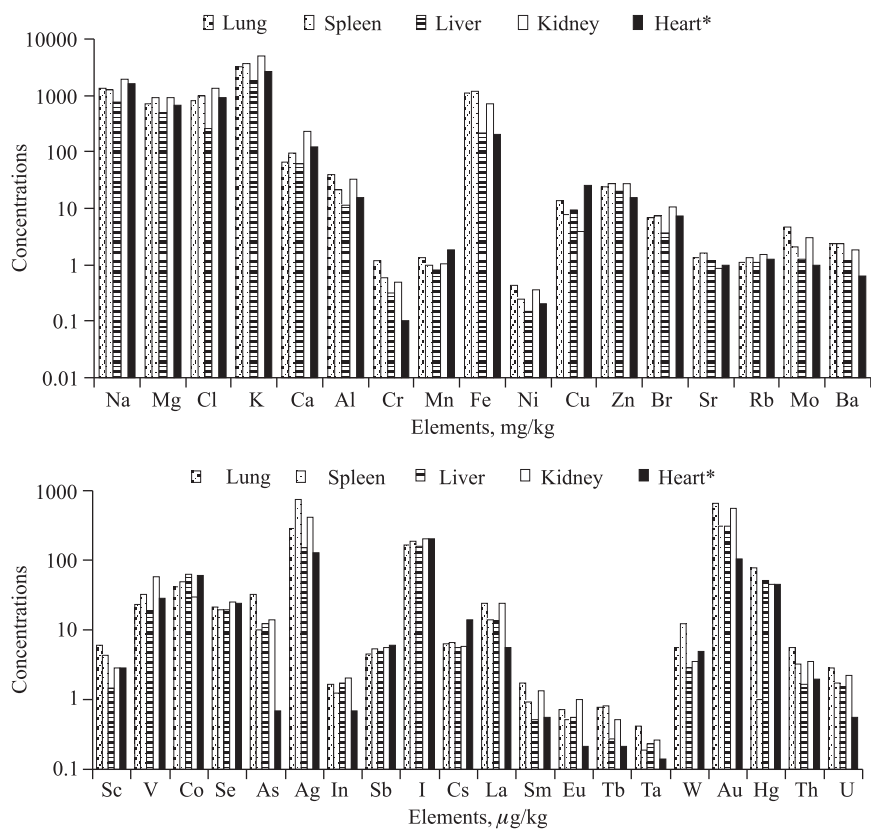


Fig. 5. Distribution of mean content of elements in lung, spleen, liver, kidney and heart

Accumulation of heavy metal and trace elements in inner organs of pasture animals from the area polluted by dust or tail is going by soil-plant-animals pathway. The total intake of metals by sheep and goats reflects the degree of soil metal enrichment and the generally higher metal concentration in pasture herbage.

Results of our study confirm the conclusion of authors [4–10].

- We concluded that inner organs of animals (sheep and goats) are suitable and useful as biological indicators for health monitoring studies of pastured animals.
- The Nuclear Analytical (INAA) Technique has sensitivity and accuracy method for the heavy metal and trace element studies of biological (such as inner organs) indicators.
- From Table 1 one can see that contents of the elements Cr, Cu, Mo, Zn, As, Sb, W, Pb are higher than in crust rocks in the tail and ores.
- From Table 8 one can find the ratios of mean content of Na and K in inner organs of the pastured animals from the polluted area 0.20:1 (liver); 0.34:1 (spleen); 0.39:1 (kidney); 0.41:1 (lung) and 0.59:1 (heart).
- Results of comparison of contents of elements are shown in Table 9 and the contents of Cr, Cu, Fe and Ba were found higher than in the ground animal data.
- From Fig. 5 one can conclude that the accumulation of biogenic elements such as Na, Mg, Cl, K, Ca and Fe is higher in inner organs of pastured animals. Also, some microelements (Cu, Zn, Mo, Ag, Au) have been found to be higher than others in inner organs of pastured animals.
- It is shown that the main pathway of these elements to inner organs is from the grasses growing on the soils of the polluted area and the waste water of the rivers Khangal and Govil near the storage of Slag-heap tail.
- Results of studies of such kind will be important to determine biogenic or essential macro-, micro- and non-biogenic or other elements in samples of human and animal body.



**Table 2. Contents ( $\Delta X$ , %) of elements in samples of nanny goat's organs**

Elements and units	6 years old nanny goat's organs				Mean contents
	Lung ( $k = 0.038$ )	Spleen ( $k = 0.027$ )	Liver ( $k = 0.018$ )	Kidney ( $k = 0.084$ )	
Na, mg/kg	1379 (9)	1458 (9)	1092 (9)	1587 (9)	1379
Mg, :-	486 (28)	1552 (21)	403 (29)	1554 (29)	999
Cl, :-	395 (2)	2422 (2)	601 (2)	1117 (2)	1134
K, :-	2538 (23)	6642 (22)	1512 (23)	7350 (23)	4510
Ca, :-	118 (18)	85.86 (31)	70 (34)	63.59 (22)	84.36
Al, :-	13.26 (6)	39.15 (7)	6.66 (7)	45.53 (7)	26.15
Cr, :-	0.28 (36)	1.73 (33)	0.07 (40)	0.40 (54)	0.62
Mn, :-	0.29 (34)	1.13 (17)	0.62 (33)	0.77 (19)	0.70
Fe, :-	85 (21)	3861 (21)	59 (21)	786 (21)	1198
Ni, :-	0.08 (48)	0.20 (45)	0.03 (45)	0.26 (51)	0.14
Cu, :-	1.33 (30)	4.72 (30)	0.74 (30)	3.62 (30)	2.60
Zn, :-	16.79 (11)	43.20 (11)	11.61 (11)	32.93 (11)	26.13
Br, :-	10.33 (25)	12.42 (25)	7.83 (25)	12.18 (25)	10.69
Sr, :-	1.03 (25)	2.46 (21)	0.42 (13)	0.45 (25)	1.09
Rb, :-	1.03 (11)	1.58 (11)	0.69 (11)	2.30 (11)	1.40
Mo, :-	0.24 (40)	2.32 (35)	0.58 (38)	0.25 (38)	0.85
Ba, :-	0.96 (32)	8.18 (32)	1.13 (32)	3.00 (31)	3.31
Sc, $\mu\text{g/kg}$	1.63 (55)	11.47 (20)	0.54 (83)	2.81 (83)	4.11
V, :-	12.54 (66)	40.23 (33)	33.66 (27)	62.58 (21)	37.25
Co, :-	31.54 (49)	41.31 (48)	33.48 (49)	50.65 (48)	39.24
Se, :-	20.10 (26)	7.40 (29)	9.14 (26)	37.63 (26)	18.57
As, :-	7.67 (60)	22.30 (56)	21.60 (70)	9.41 (40)	15.24
Ag, :-	63 (85)	132 (78)	36.18 (80)	183 (80)	103.54
In, :-	3.80 (78)	1.96 (80)	2.07 (83)	2.73 (78)	2.64
Sb, :-	3.87 (21)	8.45 (17)	3.92 (27)	7.21 (17)	5.86
I, :-	250 (30)	222 (30)	126 (30)	422 (30)	255
Cs, :-	3.71 (33)	5.24 (30)	3.24 (30)	8.40 (30)	5.14
La, :-	22.04 (35)	27.81 (32)	8.19 (45)	25.03 (26)	20.77
Sm, :-	0.89 (33)	1.07 (36)	0.19 (36)	0.81 (23)	0.74
Eu, :-	0.76 (75)	0.88 (76)	0.11 (87)	0.12 (76)	0.47
Tb, :-	0.06 (92)	2.73 (29)	0.12 (36)	0.18 (54)	0.77
Ta, :-	0.10 (41)	0.27 (39)	0.16 (44)	0.18 (47)	0.18
W, :-	8.24 (88)	41.31 (89)	5.06 (88)	4.71 (88)	14.83
Au, :-	714 (55)	337 (56)	207 (56)	311 (6)	392
Hg, :-	ND	ND	17.73 (30)	28.98 (30)	11.68
Th, :-	1.83 (19)	3.32 (16)	1.50 (24)	2.09 (18)	2.18
U, :-	1.25 (71)	1.00 (72)	0.19 (85)	2.59 (71)	1.26

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 3. Contents ( $\Delta X$ , %) of elements in samples of billy goat's organs**

Elements' symbol and units	7 years old billy goat's organs				Mean contents
	Lung ( $k = 0.0126$ )	Spleen ( $k = 0.008$ )	Liver ( $k = 0.0159$ )	Kidney ( $k = 0.028$ )	
Na, mg/kg	1207 (9)	1088 (9)	450 (9)	3248 (9)	1498
Mg, :-	737 (29)	469 (29)	461 (29)	714 (29)	595
Cl, :-	156 (3)	329 (2)	443 (2)	2259 (2)	797
K, :-	2255 (22)	1328 (22)	1940 (23)	3500 (23)	2455
Ca, :-	59 (23)	42 (25)	33 (26)	250 (23)	96
Al, :-	9.61 (7)	6.77 (7)	7.92 (7)	23.71 (8)	12
Cr, :-	0.38 (30)	0.096 (41)	0.095 (41)	0.218 (38)	0.20
Mn, :-	1.18 (8)	0.64 (9)	0.22 (19)	0.78 (15)	0.70
Fe, :-	90 (21)	51 (21)	202 (21)	294 (21)	159
Ni, :-	0.15 (49)	0.09 (45)	0.04 (48)	0.08 (48)	0.09
Cu, :-	1.61 (30)	8.56 (30)	0.82 (30)	1.61 (30)	3.15
Zn, :-	17.14 (11)	10.80 (11)	8.90 (12)	21.47 (12)	14.58
Br, :-	4.67 (25)	4.83 (25)	3.96 (25)	18.25 (25)	7.93
Sr, :-	0.41 (27)	0.35 (18)	0.30 (23)	0.81 (27)	0.47
Rb, :-	0.77 (11)	0.71 (11)	0.63 (11)	1.54 (11)	0.91
Mo, :-	1.24 (35)	0.61 (35)	0.06 (40)	0.28 (39)	0.55
Ba, :-	0.86 (32)	0.38 (32)	1.06 (32)	1.40 (32)	0.92
Sc, $\mu\text{g/kg}$	0.63 (65)	0.53 (37)	1.02 (46)	3.83 (27)	1.50
V, :-	9.45 (26)	7.44 (29)	10.65 (25)	66.92 (20)	23.61
Co, :-	40 (48)	38 (48)	8 (49)	35 (48)	30.25
Se, :-	21.92 (21)	4.40 (25)	2.38 (29)	24.36 (25)	13.26
As, :-	17.51 (36)	13.60 (36)	1.75 (53)	3.92 (53)	9.19
Ag, :-	59 (78)	51 (78)	18 (85)	59 (82)	47
In, :-	0.88 (80)	0.56 (80)	1.91 (78)	2.24 (80)	1.46
Sb, :-	6.43 (17)	2.96 (17)	1.43 (21)	7.0 (19)	4.46
I, :-	57 (30)	150 (33)	47 (30)	257 (30)	128
Cs, :-	4.41 (25)	2.08 (25)	1.91 (30)	5.04 (30)	3.36
La, :-	6.20 (45)	6.96 (29)	10.17 (25)	36.96 (23)	15.06
Sm, :-	0.45 (23)	0.32 (25)	0.16 (24)	1.4 (25)	0.56
Eu, :-	0.24 (78)	0.08 (83)	0.16 (79)	0.56 (78)	0.26
Tb, :-	0.023 (54)	0.086 (30)	0.099 (81)	0.64 (54)	0.21
Ta, :-	0.09 (59)	0.04 (45)	0.06 (25)	0.05 (54)	0.06
W, :-	7.43 (87)	5.28 (87)	1.75 (89)	4.2 (87)	4.66
Au, :-	341 (56)	124 (57)	160 (56)	733 (56)	339
Hg, :-	91 (30)	ND	ND	ND	22.75
Th, :-	1.33 (19)	1.04 (18)	0.26 (30)	1.88 (27)	1.13
U, :-	0.92 (72)	0.72 (72)	0.33 (72)	3.72 (72)	1.42

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 4. Contents ( $\Delta X$ , %) of elements in samples of sheep's organs**

Elements' symbol and units	2 years old sheep's organs				Mean contents
	Lung ( $k = 0.022$ )	Spleen ( $k = 0.021$ )	Liver ( $k = 0.01$ )	Kidney ( $k = 0.024$ )	
Na, mg/kg	807 (9)	823 (9)	280 (9)	1037 (9)	737
Mg, :-	796 (29)	817 (29)	156 (29)	1061 (29)	705
Cl, :-	43 (4)	508 (2)	24 (16)	588 (2)	285
K, :-	1892 (23)	3150 (22)	652 (23)	5016 (22)	2677
Ca, :-	41 (23)	42 (39)	12 (27)	96 (21)	48
Al, :-	131 (6)	8.95 (8)	3.06 (7)	24.24 (6)	41.81
Cr, :-	0.56 (32)	0.21 (37)	0.61 (44)	0.42 (33)	0.45
Mn, :-	0.92 (7)	0.43 (11)	0.38 (9)	0.73 (10)	0.61
Fe, :-	159 (21)	277 (21)	20 (21)	912 (21)	342
Ni, :-	0.36 (41)	0.02 (50)	0.03 (44)	0.25 (42)	0.17
Cu, :-	10.38 (30)	0.35 (30)	4.07 (30)	2.12 (30)	4.23
Zn, :-	17 (11)	15 (11)	5.45 (11)	25 (12)	16
Br, :-	4.18 (25)	4.91 (25)	0.71 (25)	7.01 (25)	4.20
Sr, :-	0.76 (26)	0.65 (27)	0.18 (37)	1.15 (25)	0.68
Rb, :-	0.74 (11)	1.21 (11)	0.40 (11)	1.44 (11)	0.95
Mo, :-	0.40 (38)	0.16 (40)	0.26 (38)	0.47 (38)	0.32
Ba, :-	2.81 (25)	0.44 (32)	0.06 (39)	1.04 (30)	1.09
Sc, $\mu\text{g/kg}$	11.4 (40)	1.47 (48)	0.16 (69)	1.01 (59)	3.58
V, :-	65.56 (20)	25.83 (27)	1.71 (33)	18.48 (28)	27.91
Co, :-	57 (48)	11 (50)	17 (48)	20 (49)	26
Se, :-	5.72 (29)	9.87 (25)	1.60 (31)	2.40 (35)	4.93
As, :-	6.82 (45)	1.05 (78)	1.80 (60)	7.44 (38)	4.28
Ag, :-	112 (78)	20 (85)	36 (78)	46 (80)	53
In, :-	0.88 (82)	0.63 (85)	0.70 (78)	2.16 (78)	1.13
Sb, :-	3.08 (21)	3.99 (17)	1.90 (17)	4.08 (19)	3.30
I, :-	203 (30)	138 (30)	124 (25)	132 (30)	149
Cs, :-	5.94 (27)	2.31 (31)	0.60 (35)	6.00 (29)	3.24
La, :-	31.7 (20)	7.14 (44)	1.3 (58)	11.8 (31)	12.98
Sm, :-	3.47 (14)	0.93 (24)	0.25 (22)	0.83(24)	1.37
Eu, :-	0,53 (77)	0.088 (86)	0.14 (78)	0.57 (77)	0.33
Tb, :-	0.83 (30)	0.28 (64)	0.049(81)	0.33 (54)	0.37
Ta, :-	0.88 (10)	0.08 (31)	0.02 (56)	0.07 (54)	0.26
W, :-	4.84 (88)	2.73 (89)	0.80 (88)	3.36 (89)	2.95
Au, :-	160 (55)	197 (55)	65 (55)	247 (55)	167
Hg, :-	151 (30)	ND	13 (32)	144 (30)	98
Th, :-	14.74 (15)	1.05 (22)	0.20 (28)	3.12 (17)	4.74
U, :-	3.52 (71)	0.80 (72)	0.40 (72)	0.48 (72)	1.30

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 5. Contents ( $\Delta X$ , %) of elements in samples of ewe's organs**

Elements' symbol and units	5 years old ewe's organs				Mean contents
	Lung ( $k = 0.013$ )	Spleen ( $k = 0.018$ )	Liver ( $k = 0.02$ )	Heart ( $k = 0.014$ )	
Na, mg/kg	731 (9)	1110 (9)	652 (9)	1596 (9)	1022
Mg, :-	355 (29)	1373 (29)	1074 (29)	693 (29)	874
Cl, :-	554 (2)	1200 (2)	76 (3)	946 (2)	694
K, :-	1254 (23)	4644 (22)	1784 (23)	2670 (22)	2588
Ca, :-	40 (27)	52 (21)	42 (19)	120 (30)	63
Al, :-	6.11 (7)	17.58 (6)	10.04 (7)	15.82 (7)	12.39
Cr, :-	0.073 (61)	0.571 (33)	0.139 (36)	0.101 (66)	0.22
Mn, :-	0.203 (41)	0.702 (25)	0.748 (25)	1.792 (11)	0.86
Fe, :-	74 (21)	1748 (21)	108 (21)	200 (21)	532
Ni, :-	0.10 (41)	0.07 (47)	0.08 (47)	0.20 (41)	0.11
Cu, :-	0.71 (30)	2.70 (30)	8.16 (30)	26.32 (30)	9.47
Zn, :-	6.58 (12)	23.04 (11)	13.90 (12)	15.96 (11)	14.87
Br, :-	5.51 (25)	7.45 (25)	4.08 (25)	7.43 (25)	6.12
Sr, :-	0.27 (35)	0.52 (28)	0.27 (47)	0.95 (25)	0.50
Rb, :-	0.40 (11)	1.13 (11)	0.58 (11)	1.26 (11)	0.84
Mo, :-	0.14 (40)	0.74 (38)	0.36 (40)	0.95 (35)	0.55
Ba, :-	0.27 (36)	1.08 (30)	1.83 (28)	0.62 (32)	0.95
Sc, $\mu\text{g/kg}$	0.58 (54)	1.55 (39)	0.76 (43)	2.87 (35)	1.44
V, :-	7.67 (30)	26.64 (26)	9.20 (28)	28.14 (25)	17.92
Co, :-	12 (52)	15 (49)	26 (48)	60 (40)	28
Se, :-	11.05 (25)	0.90 (45)	6.98 (29)	24.08 (21)	10.75
As, :-	0.65 (78)	9.54 (78)	1.0 (78)	0.70 (78)	2.96
Ag, :-	40 (78)	54 (78)	41 (78)	129 (74)	69
In, :-	0.52 (85)	0.90 (78)	1.20 (78)	0.70 (78)	0.85
Sb, :-	2.47 (21)	2.88 (23)	2.80 (24)	6.16 (17)	3.61
I, :-	192 (30)	569 (30)	306 (30)	206 (30)	318
Cs, :-	13.6 (28)	15.48 (24)	9.40 (45)	13.86 (29)	13.1
La, :-	1.56 (31)	2.34 (31)	2.0 (35)	5.60 (29)	2.86
Sm, :-	0.75 (28)	0.54 (24)	0.27 (24)	0.56 (28)	0.52
Eu, :-	0.58 (73)	0.32 (77)	0.33 (81)	0.21 (87)	0.36
Tb, :-	0.45 (66)	0.51 (88)	0.067 (41)	0.21 (54)	0.31
Ta, :-	0.091 (43)	0.054 (44)	0.08 (43)	0.14 (40)	0.09
W, :-	2.99 (87)	13.5 (87)	3.0 (88)	4.9 (88)	6.10
Au, :-	303 (55)	320 (55)	112 (58)	104 (56)	210
Hg, :-	44 (30)	ND	ND	46 (30)	45
Th, :-	0.52 (17)	2.52 (18)	1.40 (22)	1.96 (47)	1.65
U, :-	0.52 (20)	0.9 (20)	0.8 (20)	0.56 (20)	0.69

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 6. Contents ( $\Delta X$ , %) of elements in samples of sheep's organs**

Elements' symbol and units	4 years old sheep's organs			Mean contents
	Lung ( $k = 0.023$ )	Spleen ( $k = 0.024$ )	Liver ( $k = 0.038$ )	
Na, mg/kg	1662 (9)	2100 (9)	1174 (9)	1645
Mg, :-	1088 (18)	1241 (25)	741 (18)	1023
Cl, :-	395 (2)	732 (2)	50.54 (5)	392
K, :-	4232 (22)	4416 (23)	2964 (22)	3870
Ca, :-	78 (25)	129 (25)	50.54 (25)	85.84
Al, :-	18 (7)	37.2 (7)	22.19 (6)	25.79
Cr, :-	2.55 (30)	0.44 (30)	0.49 (60)	1.16
Mn, :-	1.77 (9)	1.95 (6)	1.58 (6)	1.77
Fe, :-	313 (21)	573 (21)	513 (21)	466
Ni, :-	0.47 (42)	0.52 (41)	0.26 (69)	0.42
Cu, :-	40.02 (30)	24.96 (30)	29.87 (30)	31.62
Zn, :-	25.29 (12)	47.76 (12)	52.06 (12)	41.70
Br, :-	7.47 (26)	12.43 (25)	2.40 (26)	7.43
Sr, :-	2.85 (27)	5.25 (37)	5.13 (53)	4.41
Rb, :-	1.72 (11)	2.73 (11)	3.58 (11)	2.67
Mo, :-	1.23 (36)	0.89 (36)	1.63 (36)	1.25
Ba, :-	2.81 (31)	3.05 (32)	2.0 (35)	2.62
Sc, $\mu\text{g}/\text{kg}$	2.71 (45)	6.67 (38)	4.52 (35)	4.63
V, :-	12.53 (99)	64.08 (29)	20.44 (29)	32.35
Co, :-	64.17 (48)	170 (48)	280 (48)	171.39
Se, :-	16.47 (53)	65.76 (58)	84.36 (21)	55.53
As, :-	1.64 (78)	1.21 (78)	39.52 (55)	14.12
Ag, :-	192 (75)	285 (78)	547 (73)	341
In, :-	1.67 (78)	1.38 (93)	3.76 (78)	2.27
Sb, :-	5.45 (21)	11.66 (23)	17.82 (23)	11.64
I, :-	212 (30)	35.28 (30)	337 (30)	195
Cs, :-	4.67 (33)	11.66 (37)	15.16 (44)	10.49
La, :-	12.83 (42)	23.59 (28)	39.14 (58)	25.18
Sm, :-	0.20 (23)	0.93 (28)	0.91 (21)	0.68
Eu, :-	0.49 (81)	1.08 (83)	1.08 (91)	0.88
Tb, :-	1.01 (51)	0.63 (30)	0.60 (36)	0.75
Ta, :-	0.15 (50)	0.45 (41)	0.67 (41)	0.42
W, :-	7.04 (88)	8.95 (88)	4.33 (89)	6.77
Au, :-	167 (56)	331 (56)	418 (56)	305
Hg, :-	49.91 (30)	ND	265 (30)	–
Th, :-	3.49 (21)	6.81 (20)	3.78 (29)	4.69
U, :-	4.76 (50)	3.31 (20)	3.47 (14)	3.84

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 7. Contents ( $\Delta X$ , %) of elements in samples of sheep's organs**

Elements' symbol and units	5 years old ewe's organs				Mean contents
	Lung ( $k = 0.058$ )	Spleen ( $k = 0.037$ )	Liver ( $k = 0.043$ )	Heart ( $k = 0.052$ )	
Na, mg/kg	2268 (9)	962 (9)	843 (9)	1804 (9)	1469
Mg, :-	812 (29)	196 (29)	136 (29)	336 (29)	370
Cl, :-	3271 (4)	707 (2)	429 (16)	1346 (2)	1438
K, :-	7250 (23)	1946 (22)	2339 (23)	3692 (22)	3807
Ca, :-	54 (23)	236 (39)	170 (27)	503 (21)	241
Al, :-	60 (6)	18 (8)	16 (7)	34 (6)	32
Cr, :-	3.19 (32)	0.54 (37)	0.51 (44)	0.98 (33)	1.31
Mn, :-	3.70 (7)	1.03 (11)	1.28 (9)	1.88 (10)	1.97
Fe, :-	5974 (21)	551 (21)	395 (21)	852 (21)	1943
Ni, :-	1.49 (41)	0.62 (50)	0.48 (44)	0.84 (42)	0.86
Cu, :-	30.10 (30)	6.55 (30)	12.68 (30)	8.16 (30)	14.37
Zn, :-	65.54 (11)	20.02 (11)	26.79 (11)	28.96 (12)	35
Br, :-	9.40 (25)	3.03 (25)	2.98 (25)	5.77 (25)	5.29
Sr, :-	2.49 (26)	0.67 (27)	0.84 (37)	1.07 (25)	1.26
Rb, :-	1.93 (11)	0.46 (11)	0.81 (11)	0.77 (11)	0.99
Mo, :-	25.40 (38)	7.73 (40)	4.73 (38)	10.87 (38)	12.18
Ba, :-	6.32 (25)	1.27 (32)	1.26 (39)	2.1 (30)	2.74
Sc, $\mu\text{g/kg}$	19.89 (40)	3.81 (48)	1.72 (69)	3.69 (59)	7.28
V, :-	33.64 (20)	32.56 (27)	37.84 (33)	82.68 (28)	46.68
Co, :-	48.7 (48)	13.3 (50)	12.9 (48)	15.6 (49)	22.6
Se, :-	53.36 (29)	30.71 (25)	11.61 (31)	35.36 (35)	33
As, :-	159 (45)	12.95 (78)	9.03 (60)	34.84 (38)	53.95
Ag, :-	1218 (78)	3922 (85)	241 (78)	1357 (80)	1684
In, :-	2.32 (82)	1.85 (85)	0.86 (78)	1.04 (78)	1.52
Sb, :-	5.80 (21)	1.85 (17)	2.15 (17)	3.64 (19)	3.36
I, :-	56.84 (30)	5.92 (30)	4.73 (25)	11.96 (30)	19.86
Cs, :-	5.85 (57)	2.12 (41)	2.75 (30)	4.07 (32)	3.69
La, :-	68.44 (33)	15.83 (51)	20.85 (32)	20.95 (49)	31.53
Sm, :-	4.67 (21)	1.65 (20)	1.32 (32)	2.26 (24)	2.47
Eu, :-	1.71 (36)	0.67 (47)	1.50 (36)	2.76 (35)	1.66
Tb, :-	2.25 (36)	0.56 (24)	0.67 (23)	0.88 (56)	1.09
Ta, :-	1.20 (40)	0.26 (53)	0.40 (49)	0.74 (34)	0.65
W, :-	3.41 (57)	2.07 (54)	2.30 (54)	1.56 (53)	2.33
Au, :-	2198 (52)	540 (52)	903 (52)	977 (52)	1154
Hg, :-	48.66 (65)	22.38 (65)	7.57 (63)	5.93 (72)	21.13
Th, :-	10.79 (16)	4.29 (17)	2.62 (20)	6.86 (16)	6.14
U, :-	6.44 (33)	3.44 (38)	3.99 (33)	2.12 (35)	3.99

Note: ND — none detected;  $k$  — coefficient transformation of concentration to organs' wet weight.

**Table 8. Mean contents of elements in inner organ's samples of goats and sheep**

Elements and units	Lung	Spleen	Liver	Kidney	Heart*
Na, mg/kg	1342	1257	748	1919	1596
Mg, :-	712	941	495	916	693
Cl, :-	802	983	270	1327	946
K, :-	3237	3687	1865	4889	2670
Ca, :-	65	98	63	228	120
Al, :-	39.66	21.28	11	32	15.82
Cr, :-	1.17	0.60	0.32	0.50	0.101
Mn, :-	1.34	0.98	0.80	1.04	1.792
Fe, :-	1116	1177	216	711	200
Ni, :-	0.44	0.25	0.15	0.36	0.2
Cu, :-	14.03	7.97	9.39	3.88	26.32
Zn, :-	24.72	26.64	19.79	27.09	15.96
Br, :-	6.93	7.51	3.66	10.80	7.43
Sr, :-	1.30	1.65	1.19	0.87	0.95
Rb, :-	1.10	1.30	1.12	1.51	1.26
Mo, :-	4.78	2.08	1.27	2.97	0.95
Ba, :-	2.34	2.40	1.22	1.88	0.62
Sc, $\mu\text{g/kg}$	6.14	4.25	1.45	2.83	2.87
V, :-	23.57	32.80	18.92	57.66	28.14
Co, :-	42.24	48.10	62.90	30.31	60
Se, :-	21.44	19.84	19.35	24.94	24.08
As, :-	32.22	10.11	12.45	13.90	0.7
Ag, :-	280	744	153	411	129
In, :-	1.68	1.21	1.75	2.04	0.7
Sb, :-	4.52	5.30	5.00	5.48	6.16
I, :-	162	187	157	206	206
Cs, :-	6.36	6.48	5.51	5.88	13.86
La, :-	23.80	13.95	13.61	23.68	5.6
Sm, :-	1.74	0.91	0.52	1.32	0.56
Eu, :-	0.71	0.52	0.55	1.00	0.21
Tb, :-	0.77	0.80	0.27	0.51	0.21
Ta, :-	0.42	0.19	0.23	0.26	0.14
W, :-	5.66	12.31	2.87	3.46	4.9
Au, :-	647	308	311	567	104
Hg, :-	76.91	–	50.55	44.73	46
Th, :-	5.45	3.17	1.63	3.49	1.96
U, :-	2.90	1.70	1.53	2.23	0.56

Note: \* — only one samples' result.

**Table 9. Ratio of contents (mg/kg) of Na and K in inner organs of sheep, goats and ground animals**

Elements	Ground animals	Lung	Spleen	Liver	Kidney	Heart*
Na	4000	1342	1257	748	1919	1596
K	7428	3237	3687	1865	4889	2670
Ca	200–8516	65	98	63	228	120
Mg	996	712	941	495	916	693
Na/K	0.54	0.41	0.34	0.20	0.39	0.59

**Table 10. Comparison results of mean contents for some elements of inner organs with ground animal data**

Elements	Ground animals, (mg/kg)	Inner organs of pastured animals from Mongolia, (mg/kg)				
		Lung	Spleen	Liver	Kidney	Heart
Na	4000	1342	1257	748	1919	1596
Mg	996	712	941	495	916	693
Cl	2800	802	983	270	1327	946
K	7428	3237	3687	1865	4889	2670
Ca	200–8516	65	98	63	228	120
Al	4.05–100	39.66	21.28	11	32	15.82
Cr	0.07	1.17	0.60	0.32	0.50	0.101
Mn	0.21–976	1.34	0.98	0.80	1.04	1.792
Fe	162	1116	1177	216	711	200
Ni	0.82	0.44	0.25	0.15	0.36	0.2
Cu	2.5	14.03	7.97	9.39	3.88	26.32
Zn	160	24.72	26.64	19.79	27.09	15.96
Sr	14	1.30	1.65	1.19	0.87	0.95
Rb	17	1.10	1.30	1.12	1.51	1.26
Ba	0.68	2.34	2.40	1.22	1.88	0.62
V	0.15	0.024	0.033	0.019	0.057	0.028
Co	0.03	0.042	0.048	0.063	0.030	0.060



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E-mail: [publish@jinr.ru](mailto:publish@jinr.ru)

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