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ASSESSMENT OF HUMAN ORGANISM'S INTAKE OF TRACE ELEMENTS FROM STAPLE FOODSTUFFS IN CENTRAL REGION OF RUSSIA

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Оценка поступления микроэлементов в организм человека
с продуктами питания в центральных регионах России

Изучен микроэлементный состав сырья и продуктов питания, характерных для потребительской корзины населения средней полосы России. Установлено превышение ПДК по отдельным микроэлементам, которое является следствием различных факторов, связанных с загрязнением окружающей среды, технологией производства и переработки сырья, биологическими особенностями сырья животного и растительного происхождения. Проведена оценка поступления микроэлементов в организм человека с продуктами питания двух разных рационов.

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Assessment of Human Organism's Intake of Trace Elements
from Staple Foodstuffs in Central Region of Russia

The trace element content of raw materials and foodstuffs produced from them, typical for basket of goods of residents of Central Russia, was examined. An excess of permissible levels of some trace elements was observed. This phenomenon is explained in terms of different factors such as pollution of the environment, industrial technologies, biological peculiarities of raw materials of animal and vegetable origin. An assessment of human organism's trace element intake of different food allowances is given. This study was undertaken in the framework of IAEA CRP (Contract No. 11927/R2).

The investigation has been performed at the Frank Laboratory of Neutron Physics, JINR, and the Geological Institute of Russian Academy of Sciences, Moscow.

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INTRODUCTION

It is known that out of 92 chemical elements that are found in nature 81 are found in human organism. Twelve of them are the basic or «structural» ones and constitute 99% of all elements in the organism. These elements are H, O, N, P, S, Cl, Ca, K, etc. One percent falls to the share of the rest elements, they were named trace elements (TE).

According to vital necessity for human organism, TE are subdivided [1–5, 7, 8] into the essential ones (Fe, I, Cu, Zn, Co, Cr, Mo, Se, Mn), conditionally essential ones (Br, B, F, Li, Ni, V, Si), toxic ones (Al, As, Cd, Pb, Sb, Hg, Be, Bi, Tl), and the rest, whose action on human organism is not clearly determined by now.

Apparently, this division is rather conventional. The problem of TE classification is that the essential TE at certain conditions may cause toxic reactions, while some toxic TE at certain dosage and exposure may reveal useful properties and even prove to be indispensable.

In the organism, a dynamic balance of elements occurs, which is attained with the help of interrelated processes — selective absorption, selective deposition in organs and cells, selective utilization. The disbalance may be caused by internal (genetic) and external (ecology, nutrition) reasons and may lead to various pathologies. At the pathologies, due to the essential TE, as a rule, a human being faces the diseases caused by insufficient intake of these substances. At the disbalance, due to the toxic TE, the pathologies are usually caused by excessive intake. The main path of trace element intake in human beings is through digestive tract — bowels, duodenum [3, 5, 7, 8]. Therefore, both the insufficient and excessive TE intakes into the human organism are (except for occupational specific impacts) mainly due to the peculiarities of nutrition. Obviously, the impact is practically never monoelemental.

It is known that TE have a wide spectrum of synergistic and antagonistic interactions. Hundreds of bilateral and trilateral interactions between the essential and toxic TE are known. This variety of interactions forms a basis due to which a disbalance of trace element homeostasis develops, which leads to various pathologies. That is why we need to know the concentration levels of as-wide-as-possible TE spectrum in staple foodstuffs and drinking water.

The aim of the present investigation is to assess the balance of TE intake by a human organism. Central region of Russia was chosen as a standard since up to

70% of RF population has similar living conditions with a rather unified nutrition and purification system of drinking water.

To achieve this aim, the following tasks were solved in the course of the present study:

— quantitative and qualitative assessment of population food allowances;

— analysis of trace element composition in main foodstuffs consumed by the population of Central region of Russia;

— analysis of trace element composition in drinking water in waterwork;

— assessment of human organism's intake of TE.

EXPERIMENTAL PROCEDURE

Since we were interested in the foodstuffs which were directly consumed by the population, sampling was carried out from retail trading network, farms and orchards located in the Central region of Russia. Sampling of vegetables and wild mushrooms was carried out directly in the areas where they grow in Moscow, Vladimir, Tver, and Kaluga regions. River fish was got out of the rivers of Moscow, Tver, and Astrakhan regions.

Sampling, storage, transportation, and preparation of samples for analysis were carried out in compliance with ISO and national standards.

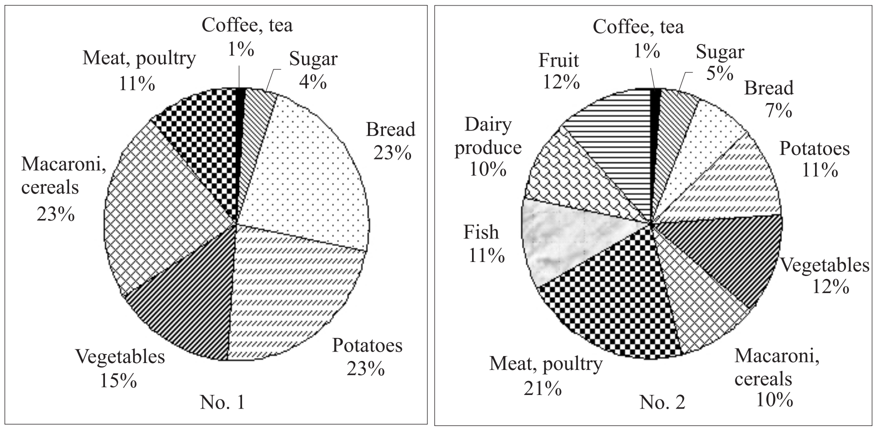
Analysis of the trace element content in the samples was carried out in the laboratories of Geological Institute of RAS (Moscow) and Joint Institute for Nuclear Research (Dubna) using atomic absorption and neutron activation analysis methods in keeping with standard procedures [13–15].

RESULTS AND DISCUSSION

In figure, two different structures of food allowances are shown. Structure of the first food allowance, which we called the base one (food allowance No. 1), constitutes a basis for the population, whose level of income corresponds to the living wage.

At present, in Russia such a level of income has 23–27% of population. This food allowance is characterized by a very small diversity of foodstuffs with the prevalence of potatoes, macaroni, and bread. As for meat, chicken is mainly consumed; as for vegetables, cabbage, carrot, and red beet are mainly consumed.

Structure of the second food allowance was arbitrarily called the main one (food allowance No. 2). Foodstuffs that are included in it are the main ones for the region population with an average level of income. It is characterized by a large diversity of foodstuffs, a decrease of intake of bread, potatoes, macaroni, and cereals, an increase of intake of meat, fish and seafood, fruit, and dairy produce.



Structure of the base (No. 1) and main (No. 2) food allowances

Table 1. **TE content in cereals, macaroni, and bread (wet weight, mg/kg)**

Element	Oats ($n = 10$)	Buckwheat ($n = 6$)	Rice ($n = 12$)	Macaroni ($n = 21$)	Bread: White wheat ($n = 11$)	Bread: Rye ($n = 16$)	RF standard
Na	46 ± 11	23 ± 5	30 ± 11	68 ± 34	855 ± 164	327 ± 130	—
K	$3\,760 \pm 270$	3410 ± 825	860 ± 510	1800 ± 500	27000 ± 3000	15000 ± 500	—
Ca	410 ± 100	530 ± 63	600 ± 125	640 ± 310	855 ± 197	308 ± 142	—
Cr	0.5 ± 0.1	0.1 ± 0.02	0.3 ± 0.2	0.2 ± 0.1	0.13 ± 0.07	< 0.05	0.2
Mn	33 ± 4	13 ± 2	6.6 ± 2	11 ± 4	7.9 ± 3.3	6.2 ± 1.8	—
Fe	59 ± 9	23 ± 5	24 ± 7	31 ± 9	36 ± 16	39 ± 15	—
Co	0.09 ± 0.01	0.07 ± 0.005	0.05 ± 0.03	0.03 ± 0.02	0.06 ± 0.03	0.04 ± 0.02	—
Ni	3.1 ± 0.2	1.8 ± 0.5	0.5 ± 0.1	0.3 ± 0.1	0.11 ± 0.03	0.16 ± 0.06	0.5
Cu	4.2 ± 0.3	4.1 ± 0.9	2.7 ± 0.4	3.8 ± 0.8	1.1 ± 0.2	1.2 ± 0.04	5–10
Zn	25 ± 1.5	15 ± 6	12 ± 2	10 ± 2	7.9 ± 4.6	9.3 ± 3.7	25–50
As	0.04 ± 0.02	< 0.01	< 0.01	< 0.03	< 0.03	< 0.03	0.1–0.3
Se	< 0.1	< 0.1	0.2 ± 0.1	0.3 ± 0.1	< 0.05	< 0.05	0.5
Br	8 ± 2	0.7 ± 0.4	20 ± 12	10 ± 1.5	2.6 ± 0.7	1.2 ± 0.3	—
Rb	4 ± 0.9	5 ± 0.8	2 ± 0.5	2 ± 0.5	9.2 ± 3.3	4.3 ± 1.8	—
Cd	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.03–0.1
Sb	< 0.01	< 0.01	< 0.01	0.06 ± 0.05	0.03 ± 0.01	0.04 ± 0.006	0.1
La	0.3 ± 0.04	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	—
Hg	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	0.01–0.03
Th	0.04 ± 0.01	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	—
Pb	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.3–0.5

Note: « — » stands for absence of data.

Table 1 presents data on TE content in cereals, macaroni, and bread. High contents of Cr and Ni are noteworthy, they are close, equal or higher than the

Table 2. **TE content in vegetables (wet weight, mg/kg)**

Element	Lettuce, spinach, dill, parsley ($n = 74$)	Maize ($n = 18$)	Legumes (beans, lentil) ($n = 31$)	Cabbage ($n = 22$)	Tomatoes ($n = 38$)	Potatoes ($n = 54$)	Carrots ($n = 57$)	RF standard
Na	222 ± 45	45 ± 24	36 ± 6	163 ± 38	14 ± 6	28 ± 19	450 ± 230	—
K,%	1.5 ± 0.4	2.7 ± 0.5	1.09 ± 0.1	0.35 ± 0.08	0.28 ± 0.04	0.52 ± 0.13	0.32 ± 0.16	—
Ca	3280 ± 1600	4333 ± 1330	1093 ± 74	224 ± 64	114 ± 57	110 ± 39	150 ± 89	—
Cr	0.32 ± 0.06	0.84 ± 0.2	0.55 ± 0.1	0.04 ± 0.02	0.04 ± 0.02	0.06 ± 0.03	0.02 ± 0.01	0.2
Mn	13 ± 4	22 ± 3	14 ± 3	3.3 ± 1	0.84 ± 0.2	1.3 ± 0.3	0.8 ± 0.3	—
Fe	57 ± 44	113 ± 96	120 ± 15	5.9 ± 2.1	4.3 ± 0.9	8.8 ± 4.3	2 ± 1	—
Co	0.05 ± 0.01	0.07 ± 0.03	0.3 ± 0.05	0.005 ± 0.001	0.004 ± 0.001	0.012 ± 0.004	0.007 ± 0.004	—
Ni	0.6 ± 0.25	0.73 ± 0.26	2.1 ± 0.3	0.15 ± 0.03	0.04 ± 0.01	0.08 ± 0.01	0.13 ± 0.03	0.5
Cu	1.8 ± 0.7	4.8 ± 0.6	9.6 ± 2.8	0.87 ± 0.1	0.47 ± 0.14	0.88 ± 0.4	0.42 ± 0.04	5
Zn	7 ± 3	16 ± 8	56 ± 7	2.2 ± 0.6	1.9 ± 0.5	4.1 ± 1.9	2.5 ± 1.3	10
As	0.021 ± 0.01	0.055 ± 0.02	< 0.01	0.008 ± 0.004	< 0.005	0.011 ± 0.002	< 0.005	0.2
Se	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.5
Br	3.2 ± 2	4 ± 2.7	13 ± 3	0.14 ± 0.03	0.35 ± 0.21	0.3 ± 0.1	0.2 ± 0.07	—
Rb	1.6 ± 0.1	2.6 ± 0.1	13 ± 2	2.1 ± 0.4	0.77 ± 0.63	1.2 ± 0.5	2.2 ± 0.6	—
Mo	0.09 ± 0.06	< 0.05	4 ± 1.5	< 0.05	< 0.05	< 0.05	< 0.05	—
Cd	< 0.01	< 0.01	< 0.05	0.01 ± 0.003	0.02 ± 0.01	0.01 ± 0.002	0.02 ± 0.01	0.03
Sb	< 0.002	< 0.002	0.025 ± 0.01	0.003 ± 0.001	< 0.002	0.002 ± 0.001	0.006 ± 0.002	0.3
La	0.13 ± 0.06	0.13 ± 0.03	< 0.01	0.01 ± 0.004	< 0.01	0.013 ± 0.0004	0.01 ± 0.005	—
Hg	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.02
Pb	0.23 ± 0.03	< 0.02	< 0.02	0.02 ± 0.009	0.03 ± 0.02	< 0.02	< 0.02	0.5

maximum allowable concentration (MAC). Besides, the contents of Cu, Se and Sb are close enough to MAC. In bread, an over-MAC content of TE was not observed. White wheat bread was enriched with such elements as Na, K, Ca, Cr, Br, and Rb; their concentrations were 2–3 times higher than in rye bread.

Table 2 illustrates data on TE content in vegetables. In leaf cultures, over-MAC contents of Cr and Ni should be pointed out, and the contents of Zn and Pb are close to MAC.

Besides, high concentrations of Mn, Fe, Co, As, Br, Rb, La, and Th are typical for leaf cultures. In maize, over-MAC contents of Cr (4 times higher), Ni, Zn are observed, also high concentrations of Mn, Fe, Co, Cu, As, Br, Rb, La, and Th are detected. In beans, MAC levels are exceeded by Cr (almost 3 times), Ni (4 times), Cu and Zn (almost 6 times).

Table 3. **TE content in fruit (wet weight, mg/kg)**

Element	Citrus plants ($n = 25$)	Bananas ($n = 15$)	Apples ($n = 35$)	RF standard
Na	24 ± 9	10 ± 0.9	12 ± 0.7	—
K, %	0.17 ± 0.02	0.33 ± 0.02	0.1 ± 0.01	—
Ca	375 ± 235	240 ± 8	90 ± 20	—
Cr	0.03 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.2
Mn	0.5 ± 0.06	1.3 ± 0.2	0.35 ± 0.06	—
Fe	4.1 ± 0.6	6.2 ± 2.8	1.9 ± 0.08	—
Co	0.006 ± 0.001	0.002 ± 0.001	0.004 ± 0.001	—
Ni	0.18 ± 0.03	< 0.03	< 0.03	0.5
Cu	0.46 ± 0.07	1.5 ± 0.2	0.2 ± 0.03	5
Zn	1.1 ± 0.3	2.4 ± 0.5	0.3 ± 0.04	10
As	< 0.005	< 0.005	< 0.005	0.2
Se	< 0.05	< 0.05	< 0.05	0.5
Br	0.11 ± 0.01	0.48 ± 0.05	0.02 ± 0.01	—
Rb	0.7 ± 0.08	3.3 ± 0.3	0.1 ± 0.04	—
Mo	< 0.05	< 0.05	< 0.05	—
Cd	< 0.01	< 0.01	< 0.01	0.03
Sb	0.004 ± 0.001	0.005 ± 0.002	<0.002	0.3
Hg	< 0.001	< 0.001	< 0.001	0.02
Pb	< 0.02	< 0.02	0.06 ± 0.01	0.5

High concentrations of Mn, Fe, Co, Br, and Rb should be pointed out. It is important to note a high Mo content in beans. These concentration levels are unique among the foodstuffs under study. Also, enrichment with K and Ca is typical for leaf cultures, maize, and beans.

In all other cases, excess of MAC is not observed. It should be pointed out that the lower TE content is characteristic of root crops and tomatoes.

Table 3 presents data on TE concentration in fruit. In column «citrus plants», the data on oranges, tangerines, and lemons are summarized. These data show that fruit is not rich in TE, TE content does not exceed the RF norm.

Table 4. **TE content in *A. campestris* (field mushrooms) and *P. ostreatus* (wet weight, mg/kg)**

Element	*Agaricus campestris* ($n = 29$)		*Pleurotus ostreatus* ($n = 14$)		RF standard
	Agrofirm	Wild	Agrofirm	Wild	
Na	52 ± 18	26 ± 14	9.4 ± 1	8.7 ± 0.8	—
K, %	0.41 ± 0.09	0.35 ± 0.12	0.36 ± 0.07	0.6 ± 0.06	—
Ca	40 ± 9	41 ± 17	81 ± 38	145 ± 53	—
Cr	0.03 ± 0.01	0.03 ± 0.02	0.01 ± 0.007	0.01 ± 0.006	0.2
Mn	0.7 ± 0.2	0.6 ± 0.3	0.5 ± 0.08	1 ± 0.1	—
Fe	3.5 ± 0.6	5.2 ± 1.9	8.9 ± 1.1	8.2 ± 3.9	—
Co	0.004 ± 0.001	0.023 ± 0.01	0.006 ± 0.004	0.011 ± 0.005	–
Ni	0.06 ± 0.04	0.06 ± 0.03	< 0.03	0.03 ± 0.006	—
Cu	2.8 ± 1.3	11 ± 8	0.7 ± 0.2	1.1 ± 0.3	—
Zn	4.6 ± 0.3	5.8 ± 0.4	4.9 ± 0.3	5.1 ± 0.3	—
As	0.02 ± 0.002	0.09 ± 0.06	0.01 ± 0.002	0.01 ± 0.004	0.5
Se	0.25 ± 0.1	1.1 ± 0.3	0.03 ± 0.02	0.03 ± 0.003	0.5
Br	0.23 ± 0.06	0.51 ± 0.3	0.05 ± 0.01	0.07 ± 0.006	—
Rb	0.8 ± 0.2	0.4 ± 0.1	1.2 ± 0.2	1.3 ± 0.1	—
Cd	0.02 ± 0.01	0.41 ± 0.3	0.02 ± 0.01	0.26 ± 0.08	0.03
Sb	0.003 ± 0.001	0.004 ± 0.003	0.001 ± 0.0007	0.001 ± 0.0007	0.3
Ag	0.01 ± 0.003	0.81 ± 0.63	0.03 ± 0.01	0.03 ± 0.007	—
Au	0.0002 ± 0.0001	0.036 ± 0.021	< 0.0001	< 0.0001	—
Hg	0.012 ± 0.006	0.55 ± 0.25	0.003 ± 0.001	0.003 ± 0.002	0.05
Pb	< 0.02	0.13 ± 0.05	< 0.02	< 0.02	0.5

Table 4 illustrates data on TE content in mushrooms — field mushrooms (*Agaricus campestris*) and *Pleurotus ostreatus* grown in different conditions. Their analysis shows that wild field mushrooms are very intensive concentrators of heavy and toxic metals: the Se content in these mushrooms exceeds MAC 2 times; Cd, almost 13 times; Hg, 11 times.

The characteristic feature of wild field mushrooms is the accumulation of noble metals (Ag and Au); concentrations of Co, Cu, As, and Pb are rather high.

It should be mentioned that high concentrations of these metals in the soil where field mushrooms had grown were not detected. In field mushrooms grown in an agrofirm in artificial conditions, concentrations of heavy and toxic metals do not exceed MAC.

For wild *Pleurotus ostreatus*, lower concentrations of heavy and toxic metals are typical: only Cd excess of MAC (almost 10 times) was detected. Here, the same tendency as with field mushrooms was observed: TE concentration in *Pleurotus ostreatus* grown in artificial conditions is significantly lower than in wild *Pleurotus ostreatus*.

Table 5. **TE content in seafood and fish (wet weight, mg/kg)**

Element	Seafood		Fish		RF standard
	Shrimps ($n = 7$)	Squids ($n = 5$)	Freshwater ($n = 25$)	Sea ($n = 20$)	
Na	9652 ± 2300	2694 ± 213	404 ± 78	1580 ± 724	—
K, %	$0{,}32 \pm 0.08$	0.15 ± 0.02	0.28 ± 0.03	0.23 ± 0.03	—
Ca	619 ± 25	139 ± 9	272 ± 110	126 ± 41	—
Cr	0.03 ± 0.01	0.04 ± 0.02	0.04 ± 0.02	0.02 ± 0.009	0.3
Mn	0.17 ± 0.05	0.46 ± 0.11	0.29 ± 0.09	0.24 ± 0.15	—
Fe	4.5 ± 0.7	1.5 ± 0.4	7.8 ± 1.7	2.8 ± 1.5	—
Co	0.097 ± 0.05	0.043 ± 0.002	0.015 ± 0.01	0.024 ± 0.011	—
Ni	< 0.03	< 0.03	< 0.03	< 0.03	0.5
Cu	1.9 ± 0.3	1.2 ± 0.1	0.28 ± 0.11	0.52 ± 0.39	10
Zn	11 ± 2.2	12 ± 2	8 ± 3.8	5 ± 0.9	40
As	8.5 ± 3.2	0.31 ± 0.04	0.028 ± 0.007	0.72 ± 0.37	1–5
Se	0.3 ± 0.1	0.13 ± 0.02	0.59 ± 0.42	0.15 ± 0.04	1
Br	191 ± 100	24 ± 2.9	1.7 ± 1.3	12 ± 5.7	—
Rb	0.4 ± 0.14	0.26 ± 0.04	0.74 ± 0.37	0.29 ± 0.07	—
Cd	0.05 ± 0.01	0.07 ± 0.04	0.01 ± 0.002	0.01 ± 0.002	0.1
Ag	0.07 ± 0.02	< 0.05	< 0.05	< 0.05	—
Sb	0.035 ± 0.01	< 0.005	< 0.005	< 0.005	0.5
Hg	0.054 ± 0.022	0.021 ± 0.004	0.042 ± 0.005	0.015 ± 0.004	0.15
Pb	< 0.02	< 0.02	0.09 ± 0.04	0.07 ± 0.02	0.5

Table 5 gives information on TE content in seafood and fish. It shows that concentrations of As and Zn are high in shrimp's meat. As seen from the table, high contents of Na and Br are typical for all seafood, including sea fish. Freshwater fish is characterized by high Se content.

Table 6 presents data on TE content in meat, livestock products, hen's eggs, and dairy produce. An over-MAC content of TE was not detected, however, it should be noted that there is rather a high content of Zn in all investigated samples, of Na and Ca in livestock products, of Na, Fe, Br, and Rb in hen's eggs, and of Br in dairy produce.

Table 6. **TE content in meat and dairy produce (wet weight, mg/kg)**

Element	Meat ($n = 14$)	Livestock (sausages, small sausages) ($n = 15$)	Hen's eggs ($n = 12$)	Dairy produce ($n = 15$)	RF standard	
					Meat produce	Dairy produce
Na	658 ± 80	5710 ± 336	1197 ± 258	275 ± 78	—	—
K, %	0.21 ± 0.05	0.11 ± 0.03	0.29 ± 0.05	0.12 ± 0.03	—	—
Ca	83 ± 6	1468 ± 44	693 ± 138	340 ± 127	—	—
Cr	0.04 ± 0.02	0.05 ± 0.02	< 0.02	0.04 ± 0.02	0.2	0.1
Mn	0.12 ± 0.02	0.21 ± 0.02	0.16 ± 0.02	—	—	—
Fe	8.2 ± 2.3	8.1 ± 0.3	40 ± 5.3	3.6 ± 1.1	—	—
Co	0.002 ± 0.001	0.003 ± 0.001	0.022 ± 0.003	< 0.002	—	—
Ni	< 0.03	< 0.03	0.06 ± 0.03	< 0.03	0.5	0.1
Cu	0.68 ± 0.09	1.2 ± 0.1	0.91 ± 0.1	0.38 ± 0.1	5	1–4
Zn	53 ± 5.2	17 ± 2.1	25 ± 4.7	4.9 ± 1.5	70	5–10
As	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.02–0.2
Se	0.08 ± 0.01	< 0.02	< 0.02	< 0.02	1	0.5
Br	1.3 ± 0.1	2.3 ± 0.7	4.7 ± 1.1	5.3 ± 1.6	—	—
Rb	1.2 ± 0.3	0.8 ± 0.4	2.5 ± 0.6	2.1 ± 0.7	—	—
Cd	< 0.01	< 0.01	0.04 ± 0.01	< 0.01	0.05	0.03–0.1
Ag	< 0.05	< 0.05	< 0.05	< 0.05	—	—
Sb	< 0.005	< 0.005	< 0.005	0.007 ± 0.002	0.1	0.05
Hg	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.005–0.02
Pb	< 0.02	< 0.02	< 0.02	< 0.02	0.3	0.1–0.3

Table 7 shows TE content in coffee, tea, and sugar. It is noteworthy that tea is quite enriched with such elements as Ca, Cr, Mn, Fe, Co, Ni, Cu, Br, Rb, Cs, and Pb, coffee has high concentrations of K, Ca, Fe, Co, Ni, Cu, Zn, Br, and Rb. Sugar is very poor in TE.

Table 7. **TE content in coffee, tea, and sugar (wet weight, mg/kg)**

Element	Coffee ($n = 16$)	Tea ($n = 15$)	Sugar ($n = 7$)	RF standard
Na	171 ± 16	57 ± 8	33 ± 6	—
K, %	4.17 ± 0.3	1.7 ± 0.09	0.002 ± 0.0005	—
Ca	1140 ± 123	2010 ± 14	530 ± 96	—
Cr	0.4 ± 0.1	3.2 ± 0.1	< 0.1	—
Mn	17 ± 2	870 ± 45	< 0.2	—
Fe	31 ± 4	117 ± 5	< 5	—
Co	0.34 ± 0.3	0.23 ± 0.01	< 0.01	—
Ni	1.4 ± 0.2	5.7 ± 0.9	0.3 ± 0.06	—
Cu	10 ± 0.5	24 ± 8	0.09 ± 0.05	1–50
Zn	5 ± 0.4	25 ± 1	0.6 ± 0.2	3–100
As	< 0.05	< 0.05	< 0.05	0.3–1
Se	< 0.1	< 0.1	< 0.1	—
Br	8.1 ± 2	6.2 ± 0.9	< 0.1	—
Rb	88 ± 6	38 ± 3	< 1	—
Cd	< 0.04	< 0.04	< 0.04	0.05–0.5
Ag	< 0.1	< 0.1	< 0.1	—
Sb	< 0.01	< 0.01	< 0.01	—
Cs	< 0.1	2.2 ± 0.1	< 0.1	—
Hg	< 0.01	< 0.01	< 0.01	0.01–0.05
Pb	< 0.1	0.5 ± 0.07	< 0.1	0.5–1

Table 8 presents the results of study of TE content in drinking water in Moscow. The comparison of these data with the national MAC and EU, WHO and USA standards shows that TE content in drinking water is significantly lower than any world standard.

In the first section of Table 9, literary data on daily need and human organism's intake of TE are presented [4–8, 11, 12, 16–18]. Their analysis shows that daily TE intake corresponds to the need. A slight lack of Mn intake and a rather large excess of Co and Ni are observed.

The second section of Table 9 summarizes data on TE intake that were obtained by the authors by means of calculation on the basis of the average daily rate of intake (food allowances No. 1 and No. 2) using the information given in Tables 1–8. The amount of food intake per adult was assumed to be 1.4 kg/day;

of water, 2 l/day. The values obtained in this way agree rather well with literary sources, though there are some deviations. The assessment of human organism's intake of individual elements with foodstuffs and drinking water is given in Table 9.

Table 8. **TE content in drinking water, mg/l**

Element	Drinking water, Moscow, $n = 25$	WHO standard [9]	USA standard [9]	EU standard [9]	RF standard [10]
Na	60 ± 5	200	—	200	—
K,%	20 ± 5	—	—	—	—
Ca	44 ± 4	—	—	—	—
Cr	0.00004 ± 0.00001	0.05	0.1	0.05	0.05
Mn	0.003 ± 0.001	0.1	—	0.05	0.1
Fe	0.046 ± 0.02	0.03	—	0.2	0.3
Co	< 0.0002	—	—	—	—
Ni	0.0006 ± 0.0003	0.02	—	0.02	0.1
Cu	0.002 ± 0.001	2	1.3	2	1
Zn	0.036 ± 0.02	3	—	5	5
As	0.00015 ± 0.00003	0.01	0.05	0.01	0.05
Se	< 0.0002	0.01	0.05	0.01	0.01
Br	0.02 ± 0.005	—	—	0.01 (bromate)	0.2 (bromides)
Mo	0.00003 ± 0.00001	0.07	—	—	0.25
Ag	< 0.00005	—	—	—	—
Cd	0.0000012 ± 0.0000006	0.003	0.005	0.005	0.001
Sb	< 0.0005	0.005	0.005	0.001	0.003
Hg	< 0.0002	0.001	0.002	0.001	0.0005
U	0.0005 ± 0.0001	0.002	—	—	—
Pb	< 0.0002	0.01	0.015	0.01	0.03

Na. It belongs to basic or structural elements. The main role of Na in the organism is the maintenance of osmotic pressure of extracellular liquids. Na content in human organism is approximately 100 g. Its need is assessed to be 1.4–1.6 g/day. In fact, its intake, in accordance with food allowance No. 1, is almost 2 times smaller, in accordance with food allowance No. 2, Na intake is slightly lower than necessary. This is due to the fact that we analyzed Na content in raw foodstuffs without taking into account table salt, which is added during food preparation. According to literary data, taking into account the addition of salt into foodstuffs, human organism's intake of Na is within the norm.

Table 9. **Human organism's intake of TE, mg/day**

Element	Literary data		Experimental results	
	Need	Intake	Food allowance No. 1	Food allowance No. 2
Na	1400–1600	500–1500	800	1200–1600
K	2000–3000	2000–6000	8000	4000–5900
Ca	1000	1100	820	730–885
Cr	0.05–0.2	0.3	0.19	0.16
Mn	2–9	0.4–10	18	16–19
Fe	10–30	7–8	33	16–18
Co	0.04–0.1	0.3	0.035	0.04–0.06
Ni	0.005–0.6	0.3–0.6	0.33	0.27–0.32
Cu	2–5	4–5	2.8	2.1–4.4
Zn	6–30	13	15	17–19
As	—	1–10	0.008	0.007–0.8
Se	0.1–0.15	0.06–0.33	0.13	0.15–0.24
Br	—	7.5	5.3	4.1–13
Rb	—	1.5–6	4.9	3.7
Mo	0.3	0.05–0.3	< 0.05	0.24
Ag	—	0.07–0.1	< 0.05	< 0.05
Cd	—	0.01–0.2	0.007	0.005–0.11
Sb	—	0.002–0.1	0.06	0.02
Hg	—	0.001	< 0.002	0.006–0.089
Pb	—	0.2–0.3	0.01	0.023–0.048

K. It is a structural chemical element. Potassium plays the main part in intracellular exchange, in maintenance of osmotic pressure, in ion mechanisms of excitation in peripheral and central nervous systems. K content in human organism is 140 g. K need is within 2–3 g/day. The real intake is considerably higher: in accordance with food allowance No. 1 it is 8 g/day; and with food allowance No. 2, 4–5.9 g/day.

Ca. It is a representative of structural element group. Calcium plays a key role in nervous excitation transfer, maintenance of cell membrane integrity, construction of bones. Ca content in human organism is approximately 1000 g. More than 99% is a part of bones and enamel. Ca need is 1 g/day. The real intake with both food allowances is somewhat lower than necessary — 0.8–0.9 g/day.

Cr. It refers to essential elements. Chrome metabolism is rather complex due to various valent states, which determine its features of behavior in the organism. It is a part of fermentative systems, it participates in the exchange of nuclein acids. Lack of chrome may cause hyperglycemia and glucosuria, which remind of the phenomena of moderate diabetes. At present, there are no reliable data on Cr content in human organism. Cr need is 0.05–0.2 mg/day; toxic dose, 200 mg/day. The real intake with food allowances No. 1 and No. 2 is 0.16–0.19 mg/day.

Mn. It belongs to essential elements. Manganese is a part of fermentative systems with non-specially exchanging metal components. It influences the activity of a number of ferments. It is known that manganese is accumulated by thyroid gland, and it participates in formation of iodine-containing proteins. Mn content in human organism is 12 mg. Its need is 2–9 mg/day. The real intake with both food allowances is approximately 2–3 times higher than necessary.

Fe. It refers to essential elements. It is a part of hemoglobin; it participates in the processes of binding and transporting of oxygen to tissues; it stimulates the function of hemopoietic organs; it is used as a medicine for anemia. Fe content in human organism is 4.2 g. Fe need is 10–30 mg/day; toxic action may occur at a dose of 200 mg/day. The real intake with food allowance No. 1 is somewhat larger than necessary — 33 mg/day, it is within the need with food allowance No. 2.

Co. It is a representative of essential element group and is one of the most important trace elements. Co influences blood formation and metabolism, it plays the most important role at endogenous synthesis of vitamin B_{12}. The excess of Co stimulates marrow to produce red corpuscles, it also oppresses the ability of thyroid gland to accumulate iodine, i.e. goiter disease may result from the intake of Co salts at anemia. Its content in human organism is 14 mg. Co need is 0.04–0.1 mg/day; toxic dose, 200–500 mg/day. The real Co intake with food allowance No. 1 is 0.035 mg/day; with food allowance No. 2, 0.04–0.06 mg/day depending on food preferences.

Ni. At present, it is referred to conditionally essential elements. Conclusive proofs that nickel is vitally important for animals and human beings have not been obtained yet. The data on Ni content in the organism are rather inconsistent, various researchers give figures differing by an order — from 1 to 10 mg. As for its need, the discrepancy is even more considerable — from 0.005 to 0.6 mg/day. The real Ni intake with both food allowances is 0.3 mg/day.

Cu. It belongs to essential elements. It is a part of metallic–proteid, controlling electronation reactions of cellular breathing, photosynthesis, assimilation of molecular nitrogen, it is a component part of hormones. Its content in human organism is 72 mg. Cu need is 2–5 mg/day, toxic action occurs at a dose of more than 250 mg/day. The real Cu intake with food allowance No. 1 is 2.8 mg/day; with food allowance No. 2, 2.1–4.4 mg/day.

Zn. It is a representative of essential element group and is one of the most important trace elements. It is a part of the most important ferments; it participates in the exchange of nuclein acids and protein synthesis. It influences the main living processes: blood formation, reproduction, growth and development of the organism, exchange of carbohydrates, fats and proteins, electronation reactions, energy exchange. Its content in human organism is 2.3 g. Its need is 6–30 mg/day;

toxic action occurs at a dose of 300–600 mg/day. The real intake with food allowance No. 1 is 15 mg/day; with food allowance No. 2, 17–19 mg/day; i.e. it is within the norm.

As. It belongs to toxic elements, in a number of biological processes it can substitute phosphorus. It is considered to be carcinogenic for human beings. However, it was determined that the lack of As leads to oppression of growth and birth rate in experimental animals. As content in human organism is 18 mg. As need is not determined; toxic dose is 10–50 mg/day. The real intake with food allowance No. 1 is 0.008 mg/day; with food allowance No. 2, 0.007–0.8 mg/day. The significant difference in As intake can be accounted for by the fact that the second value was calculated taking into consideration the intake of seafood, which is the richest As source for food.

Se. It is an essential element. At present, it is considered to be one of the most effective antioxidants. It plays an important role in the exchange of proteins, fats, and carbohydrates, in the regulation of many fermentative reactions, and in electronation processes. It is known that Se can prevent poisoning by Cd and Pb. Human organism contains 14 mg of selenium. Se need is 0.1–0.15 mg/day; Se lack develops as the Keshan disease or cardiomyopathy at the intake of less than 0.01 mg/day. Its toxic dose is 55 mg/day. The actual intake with food allowance No. 1 is 0.13 mg/day; with food allowance No. 2, 0.15–0.24 mg/day. The highest value of Se intake with food allowance No. 2 is also connected with seafood intake.

Br. It is a representative of conditionally essential elements. Biological role of Br in living organisms is not studied properly. Bromine is known to be a constant component part of the normal gastric juice causing its acidity together with Cl. Br compounds oppress the function of thyroid gland and increase hormone activity of adrenal cortex. Br content in human organism is 260 mg; its need is not determined by now; it has toxic action at a dose of 3 g/day. The actual intake with food allowance No. 1 is 5.3 mg/day; with food allowance No. 2, 4.1–13 mg/day. The second value of intake with food allowance No. 2 is due to the intake of sea and river fish, seafood, vegetables and coffee.

Rb. By now, its biological role is not determined for sure. Rubidium is found in all living organisms, it is a satellite of potassium. Probably, it has to do with nervous conductivity. In human organism, there is 680 mg of rubidium. Its need is not determined; it is not toxic. The actual intake with food allowance No. 1 is 4.9 mg/day; with food allowance No. 2, 3.7 mg/day.

Mo. It belongs to essential elements. Mo role in metabolism is caused by its inclusion into the composition of several ferments. Its metabolism in the organism is, to a certain extent, similar to the metabolism of phosphorus. Continuous intake of excessive doses of molybdenum results in the violation of P–Ca exchange, deformation of the extremities, weakness. There are no reliable data on Mo content in human organism. Its need is 0.3 mg/day; toxic dose is

5 mg/day. Its real intake with food allowance No. 1 is less than 0.05 mg/day; with food allowance No. 2, 0.24 mg/day, which is entirely due to the intake of the legumes (beans, lentil).

Ag. At present, its biological role is not studied properly. Silver is known to have antiseptic action, moreover, it has nonspecific action on fermentative systems. There are no reliable data on Ag content in human organism and on its need. Its toxic dose is 60 mg/day. The real intake with both food allowances is less than 0.05 mg/day on condition that wild mushrooms are not eaten (Table 4).

Cd. It is a toxic element. It is known that cadmium similar to copper and zinc reduces adrenaline hyperglycemia, but it does not influence sugar content in blood by itself. It influences the exchange of carbohydrates. Cadmium compounds are highly toxic; they cause nephritis, adipose degeneration of liver and heart, intestinal bleeding and have carcinogenic effect. There is 50 mg of Cd in human organism; toxic action may become apparent at the intake of 3–5 mg/day. The real intake with food allowance No. 1 is 0.007 mg/day; with food allowance No. 2, 0.005–0.11 mg/day.

Sb. Currently, there are no reliable data on Sb role in metabolism in human organism. According to its properties, antimony is close to arsenic. Sb oppressive influence on the ferments participating in the exchange of carbohydrates, fats and proteins was ascertained. Similar to arsenic, antimony reacts with sulfhydryl groups, has toxic and carcinogenic properties. Human organism contains approximately 2.5 mg of antimony; toxic action is possible at a dose of 100 mg/day. The real intake of Sb with food allowance No. 1 is 0.06 mg/day; with food allowance No. 2, 0.02 mg/day.

Hg. It belongs to highly toxic elements. In the chronic case, nervous system is affected, motor functions and secretion of alimentary tract are deteriorated. Toxic action of mercury depends strongly on its chemical shape. Inorganic salts of bivalent mercury cause deterioration of kidney functioning, while methylmercury mainly deteriorates the functioning of peripheral and central nervous systems. According to different assessments, human organism contains 10–15 mg of mercury, it has toxic action at a dose of 0.4 mg/day. The real intake of mercury with food allowance No. 1 is less than 0.002 mg/day; with food allowance No. 2, 0.006–0.089 mg/day. The highest value of intake with food allowance No. 2 is rather close to the toxic dose and is due to seafood intake, especially of shrimp's meat.

Pb. It belongs to toxic elements. Toxic action of lead is characterized by the influence on heme and hemoproteins, which results in decrease of the level of hemoglobin circulating in blood, lead also effects the activity of red corpuscles. Lead is known to have influence on peripheral and central nervous system. At present, it was demonstrated that even at low levels of lead influence the decrease in rate of nervous conductivity is possible. Human organism contains 120 mg of lead, 95% of which is located in bones. Toxic action may become apparent at the intake of 1 mg/day. The real intake with food allowance No. 1 is 0.01 mg/day; with food allowance No. 2, 0.023–0.048 mg/day.

CONCLUSIONS

As a result of the present study, trace element content of staple foodstuffs which are typical for intake by the population of the central part of Russia was determined. The data on TE content in Moscow drinking water are presented, their intake by human organism with the main food allowances was assessed. Evaluating the results of the present study, we came to the following conclusions:

1. An over-MAC content of some TE, including the toxic ones, in various staple foodstuffs appears to be rather a widespread phenomenon. This may be due to several reasons: local or regional peculiarities of soil, on which agriproducts are grown; usage of fertilizers made from phosphorite (As, Cd, U); usage of leaded gasoline (Pb); ecological reasons. However, the main reason, in the authors' opinion, is the difficulties in development of effective systems of monitoring of TE content in staple foodstuffs.

2. The poorest TE content is in fruit and sugar; the richest TE content is in wild mushrooms, seafood, fish, vegetables (especially maize, legumes, and leaf cultures).

3. On assessing the results of human organism's intake of TE with food allowances No. 1 and No. 2, to our mind, we obtained rather paradoxical results. It proved to be that the most optimal is TE intake with food allowance No. 1, which corresponds to the living wage and is poor concerning the diversity of foodstuffs. Intake of all the studied TE is within the need. At the intake of a more diverse food allowance No. 2, a violation of balance of TE intake may occur (an increase in the intake of essential and toxic TE, when the intake of certain TE may be close to the toxicity edge).

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