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HYGIENIC ANALYSIS OF PUBLIC HEALTH RISKS FROM CONSUMPTION OF FOOD PRODUCTS CONTAMINATED WITH HEAVY METALS

Environmental pollution poses a serious threat to public health, being a key factor in the development of many diseases. Of particular danger are substances with carcinogenic properties. For industrial cities such as Ufa with a developed petrochemical industry, this problem is especially relevant. The observed increase in cancer incidence in the region requires a comprehensive risk assessment and the development of effective preventive measures.

In this work, an assessment of the health risk to the population of Ufa associated with chemical contamination of food products with heavy metals was carried out in accordance with the «Guidelines for assessing the risk to public health from exposure to chemicals polluting the environment» (R 2.1.10.3968-23).

The study revealed specific patterns of accumulation of toxic elements in different groups of products: dairy products demonstrate elevated concentrations of Pb, Cd and Ni; meat products – Hg; fruit and vegetable products – As. Analysis of the dietary structure showed the dominant role of dairy (31%), bread (18%), fruit and vegetable (12%) and meat (11%) products in the formation of the daily diet. An excess of the permissible level of non-carcinogenic risk for arsenic (HQ = 1.143) was revealed, indicating a potential danger to the nervous and cardiovascular systems. The total carcinogenic risk is at an acceptable level (1.39×10-5), with the main contribution of cadmium (52%) and arsenic (43%). The data obtained emphasize the need for priority control of As and Cd content in food products, development of targeted preventive measures, and optimization of the food monitoring system.

Keywords: heavy metals, carcinogenic and non-carcinogenic risk, food products.

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Introduction. In the context of the growing environmental crisis, environmental pollution remains one of the key global problems. Numerous studies show that most human diseases are caused by the impact of environmental factors, which are either the direct cause of pathologies or contribute to their development, with the carcinogenic potential of pollutants posing a particular danger [3, 6, 9 For large cities, in particular for Ufa, the capital of the Republic of Bashkortostan, with its developed petrochemical industry, such studies remain relevant, requiring a comprehensive approach taking into account local environmental characteristics. The region has seen a steady increase in cancer incidence [10], one of the most important tools for preventing it is the assessment of carcinogenic and non-carcinogenic risks, followed by the development of measures to minimize them.

Heavy metals are a group of chemical pollutants present in the biosphere both as a result of natural geochemical processes and as a result of anthropogenic impact on the environment [1, 16].

The main route of human exposure to heavy metals is through the food chain as a result of consuming contaminated foods. Food contamination with heavy metals poses a serious threat to public health. According to WHO, more than 20% of nutrition-related diseases are caused by exposure to toxic elements, including lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As) [12, 15].

Natural concentrations of heavy metals are determined by the geochemical characteristics of the territories, while anthropogenic activity leads to their migration and accumulation in atypical ecological niches [15]. It should be noted that metals play a dual biological role. Despite the participation of heavy metals in key metabolic processes, when they accumulate in excess in the body, they exhibit pronounced toxic properties, leading to the development of pathological conditions [11]. For example, the essential element copper, being an irreplaceable participant in oxidation-reduction processes, exhibits neurotoxic, hepatotoxic and nephrotoxic effects when physiological concentrations are exceeded [5]. Zinc, being one of the essential chemical elements for the body, is involved in the regulation of many enzyme systems, protein and nucleic acid synthesis, but when consumed in excess, it can cause gastrointestinal disorders, weakened immunity, neurological problems, copper deficiency and anemia [14]. At the same time, elements such as mercury, lead, and cad-

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mium exhibit pronounced toxicity even at minimal concentrations and do not participate in the physiological processes of the body. Despite the fact that arsenic is a very strong poison in high doses, some studies indicate its potential role in metabolism at minimal concentrations [7].

Purpose of the work: Assessment of the health risk to the population of the city of Ufa associated with chemical contamination of food products with heavy metals.

Materials and methods.

The calculation of the risks to public health due to oral intake of heavy metals from food products was carried out in accordance with the "Guidelines for assessing the risk to public health from exposure to chemicals that pollute the environment" (R 2.1.10.3968-23). The average daily dose was calculated using the formula

LADD=[C×CR×ED×EF] / [BW×AT×365], (1)

where: LADD – average daily dose, mg/(kg×day); C – concentration of the substance in the polluted environment, mg/kg; CR – food intake, kg/day; ED – exposure duration, years (ED=30 years); EF – exposure frequency, days/year (EF=365 days per year); BW – human body weight, kg (BW=70 kg); AT – exposure averaging period (for chronic non-carcinogenic effects AT = 30 years, for carcinogens AT =70 years); 365 – number of days per year.

Individual carcinogenic risk (CR) was estimated for cadmium, arsenic and lead by multiplying the values of the average daily lifetime dose, the slope factor and the malignancy severity coefficient. A hazard quotient (HQ) for non-carcinogenic effects, which is the ratio of the estimated dose of a pollutant to its safe exposure level, has been determined for cadmium, arsenic, mercury, nickel, zinc and copper. For substances with a similar toxicity mechanism, hazard indices (HI) have been calculated, quantitatively characterizing the combined effect on critical target organs.

Food products that form the basis of the diet of the population of the city of Ufa were divided into the following categories: meat and meat products, bread and bakery products, milk and dairy products, vegetables, potatoes, eggs, fish and fish products, fruits, vegetable oil and other fats, sugar and confectionery. Quantitative analysis of the content of elements (Pb, Cd, As, Hg, Ni, Zn, Cu) was performed in the chemical analysis department of the Testing Center of the Federal Budgetary Scientific Institution "Ufa Research Institute of Occupational Medicine and Human Ecology" (unique accreditation record number in the register of accredited persons ROSS RU.0001.510411) using the atomic absorption method with flame and graphite atomization on Varian AA spectrophotometers models 240FS and 240Z (Australia). Sample preparation was carried out using the Speedwave Xpert microwave system (Germany). A total of 3250 food samples were analyzed.

Data on actual food consumption were collected using a food diary method, where respondents recorded their entire diet for 10 days. The research sample (n=286) was formed from among adult urban residents who met the following criteria: satisfactory self-assessment of health, absence of chronic pathology, moderate alcohol consumption, absence of nicotine addiction and professional contact with heavy metals.

The study data were statistically analyzed using Microsoft Excel 2016 and Statistica (version 21.0) software. The study results were processed using standard methods of descriptive statistics, in particular, the calculation of mean values with standard deviations.

Results and discussion. An assessment of the content of elements in the main groups of food products showed a predominant accumulation of nickel in dairy products; arsenic in fruit and vege-

Table 1

Metal content in food products for exposure calculation, mg/kg

Food group	lead	cadmium	arsenic	mercury	copper	zinc	nickel
Meat and meat products	0.124±0.093	0.04±0.03	0.0028±0.0006	0.0029±0.0003	1.34±0.27	18.44±3.96	0.07±0.02
Bread and bakery products	0.066±0.010	0.010±0.001	0.0051±0.0004	0.0004±0.0001	1.91±0.36	14.01±2.11	0.33±0.02
Milk and dairy products	0.072±0.019	0.025±0.013	0.0010±0.0001	0.00004±0.00001	0.19±0.06	3.43±0.74	0.98±0.24
Vegetables	0.013±0.009	0.022±0.002	0.0091±0.0010	0.0006±0.0002	1.13±0.15	4.07±1.49	0.97±0.19
Potato	0.174±0.080	0.012±0.002	0.0089±0.0002	0.0006±0.0001	1.26±0.06	3.53±0.44	0.81±0.26
Eggs	0.091±0.030	0.007±0.002	0.0006±0.0004	0.0010±0.0007	0.38±0.03	8.48±1.36	0.12±0.06
Fish and fish products	0.024±0.009	0.012±0.004	0.0090±0.0023	0.0044±0.0010	0.96±0.19	2.72±0.33	0.89±0.20
Fruits	0.088±0.019	0.016±0.005	0.0069±0.0014	0.0024±0.0008	0.41±0.09	0.38±0.08	0.38±0.04
Vegetable oil and other fats	0.075±0.015	0.014±0.005	0.0001±0.0001	0.0060 ±0.0020	0.07±0.03	0.45±0.12	0.39±0.10
Sugar and confectionery	0.102±0.024	0.007±0.002	0.0041±0.0007	0.0006±0.0001	1.55±0.19	4.09±0.76	0.15±0.06

Table 2

Среднедушевое потребление пищевых продуктов жителями г. Уфы

Food group Products	Food consumption, kg/day
Meat and meat products	0.177
Bread and bakery products	0.280
Milk and dairy products	0.485
Vegetables	0.175
Potato	0.126
Eggs	0.017
Fish and fish products	0.035
Fruits	0.155
Vegetable oil and other fats	0.050
Sugar and confectionery	0.077

table products; lead in potatoes and meat products, copper in bread and bakery products, cadmium and zinc in meat and meat products, and mercury in fish products (Table 1).

A study of the average per capita consumption of food products by the population of Ufa showed a high level of consumption of milk and dairy products (31% of the total daily intake), bread and bread products (18%), meat and meat products (12%), and fruit and vegetable products (11%) (Table 2).

The distribution of the studied food groups by the level of contribution to the exposure to metals revealed that the maximum dose load of cadmium, lead, nickel and copper is contributed by milk and dairy products (Table 3). Similar studies have identified areas with elevated levels of exposure to toxic elements. In particular, for certain areas of the Orenburg and Saratov regions, maximum values of the contribution of milk and dairy products to the total dose load of lead and cadmium have also been recorded [4, 8]. In terms of arsenic exposure, priority products are vegetables, and in terms of mercury exposure, meat and meat products. In terms of zinc accumulation, bread and bakery products occupy a leading position.

A quantitative assessment of non-carcinogenic risk, carried out using the method of calculating hazard coefficients (HQ), revealed that for the health of the population of Ufa, exposed to oral exposure to heavy metals with food products, arsenic (HQ = 1,143) represents the greatest potential hazard in comparison with other studied elements (Table 4).

An analysis of the health risk of the population for critical organs and systems revealed that the following are at the greatest risk of developing negative effects: the nervous system and human development (the risk index for the development of non-carcinogenic effects HI = 1,158), the cardiovascular system, respiratory organs, and skin (HI = 1,143). This level of risk is considered acceptable and is associated with the intake of arsenic and mercury with food. Despite the acceptable level of risk, constant monitoring of the content of these elements in food products is required due to the cumulative effect and latency of manifestations (symptoms may appear after 5-15 years). Particular attention should be paid to protecting the health of pregnant women and children, since exposure to toxicants during this critical period can cause persistent, irreversible neurodevelopmental disorders. For the immune system, gastrointestinal tract, kidneys and blood, the risk level is minimal (HI = 0,051 – 0,070).

A comparative analysis revealed a high consistency of the results with the data of modern studies on the assessment of risks of heavy metals in industrial regions of Russia. The dominant role of arsenic as a priority pollutant in the Orenburg, Arkhangelsk, and Samara regions was revealed [2, 4, 13]. The HQ values for arsenic (our data: 1,143; Orenburg region: up to 1,8; Arkhangelsk region: 0,9–1,2, Samara region: 1,9) indicate that the threshold is exceeded in industrial zones, with uniform conclusions about critical target systems (nervous, cardiovascular system, skin, respiration).

Individual cancer risk, which refers to the probability of developing a malignant tumor during a person's lifetime, was calculated for the following elements:

Table 3

Contribution of major foods to total heavy metal exposure, %

Food group Products	Химический элемент						
	Pb	Cd	As	Hg	Ni	Zn	Cu
Meat and meat products	17.26	22.4	7.77	29.38	1.17	30.67	1.17
Bread and bakery products	14.53	8.86	21.63	5.91	9.48	36.86	9.48
Milk and dairy products	27.46	38.37	3.67	1.08	48.78	15.63	48.78
Vegetables	1.79	12.18	23.86	6.44	17.45	6.69	17.45
Potato	17.24	4.78	16.99	4.48	10.46	4.18	10.46
Eggs	1.22	0.38	0.15	1.01	0.21	1.35	0.21
Fish and fish products	0.66	1.33	4.88	9.13	3.21	0.89	3.21
Fruits	10.72	7.85	16.20	22.05	6.05	0.56	6.05
Vegetable oil and other fats	2.95	2.14	0.007	17.78	2.00	0.21	2.00
Sugar and confectionery	6.17	1.71	4.78	2.74	1.19	2.96	1.19

Table 4

Assessment of the hazard coefficient for the development of non-carcinogenic effects on critical organs/systems

Chemical element	Average daily exposure, mg/kg	Safe exposure level of the substance, mg/kg	Hazard factor	Critical organs and systems
Cd	$1.94 \cdot 10^{-5}$	0.0005	0.038	kidneys
As	$4.04 \cdot 10^{-6}$	0.0000035	1.143	development, cardiovascular system, nervous system, respiratory system, skin
Hg	$2.41 \cdot 10^{-6}$	0.00016	0.015	nervous system, development, kidneys
Ni	0.0014	0.02	0.070	systemic
Zn	0.0152	0.3	0.051	immune system, blood
Cu	0.0021	0.04	0.052	Gastrointestinal tract

Table 5

Individual carcinogenic risks from oral intake of heavy metals

Heavy metal	Average daily exposure, mg/(kg·day)	Slope factor $(mg/kg \cdot day)^{-1}$	Carcinogenic risk	Level of carcinogenic risk
As	$4.04 \cdot 10^{-6}$	1.5	$6.00 \cdot 10^{-6}$	Acceptable
Pb	$7.79 \cdot 10^{-5}$	0.0085	$6.63 \cdot 10^{-7}$	Minimum
Cd	$1.94 \cdot 10^{-5}$	0.38	$7.22 \cdot 10^{-6}$	Acceptable
Total carcinogenic risk			$1.39 \cdot 10^{-5}$	Acceptable

arsenic, cadmium, and lead. Cancer risk was estimated based on average daily exposure data and slope factors (Table 5). The slope factor (SF), also known as the carcinogenic potency factor, is a key parameter used to quantify carcinogenic risk. The severity factor value was taken to be 1.

The permissible level of carcinogenic risk is formed due to the content of cadmium and arsenic in food products, which is consistent with the results of tests conducted in the Samara and Saratov regions [2, 8]. The minimum risk was recorded from the intake of lead. The overall risk level from all the metals studied is considered permissible (acceptable) for the population.

Conclusion. Thus, the assessment of potential harm to the health of the population of Ufa revealed the presence of both non-carcinogenic and carcinogenic risks associated with the consumption of food products. A priority non-carcinogenic risk from arsenic (HQ=1,143) was identified, chronic exposure to which is associated with damage to the nervous and cardiovascular systems and skin pathology (HI=1,143-1,158). An acceptable total carcinogenic risk ($\Sigma CR=1,39\times10^{-5}$) was established with the dominance of cadmium (52%) and arsenic (43%).

The obtained data emphasize the need to develop a differentiated approach to quality control of food products, taking into account the specifics of the accumulation of heavy metals in various food products, average per capita consumption, and the characteristics of the toxicological effects of individual elements.

The results of the study create a basis for improving the food safety monitoring system and developing preventive measures aimed at reducing health risks for the population of industrial cities. Of particular importance is taking into account regional characteristics, both in the structure of nutrition and in the nature of food contamination.

In the future, it is also planned to study the health risk of the city's children's population from oral intake of heavy metals with food products, study the seasonal dynamics of food contamination, and conduct biomonitoring of the population to identify the accumulation of heavy metals in the human body.

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