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POPULATION HEALTH RISK ASSESSMENT FROM CONTAMINATION OF FOOD PRODUCTS WITH CONTAMINANTS (C.D. SAMARA, C.D. TOGLIATTI)

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Abstract. The introduction in socio-hygienic monitoring of methodologies for risk assessment of negative impact on human health of food contamination with chemical substances was carried according to the methodical documents intended for practical use in Rospotrebnadzor, allowing to select a system of formulas, necessary for research, built in sequence: the dynamics of the amount of the studies presented to the federal information fund of public health monitoring for the long period of time, the sampling of products and food contaminants, depending on the amount of information data, the calculation of the median and the 90th percentile, the exposure of contaminants in foods, the percentage distribution of the contribution of food groups in exposure, the risk of non-carcinogenic and carcinogenic effects.
Key words: socio-hygienic monitoring, contamination of food, health risk assessment.

The socio-hygienic monitoring (SHM) conducted by Rospotrebnadzor in Samara Region (hereinafter – Agency) includes a study of food product and food stock safety, analysis of the regulated indicators based on laboratory studies. SHM for the purposes of hygienic diagnostics includes a public health risk assessment program. Chemical exposure was assessed (quantitative assessment of the level of contact with the chemical reagent over a period of time) following the guidelines of the section "Contamination of food products by chemical substances"; calculations and assessment of potential carcinogenic and non-carcinogenic risks – health hazard likelihood [2, 3, 5]. Foreign substances may have a negative impact on organs and trigger a disease. Hazardous substances often may accumulate in a human body resulting from chronic administration with food products.

The analyzed contaminants are for chemicals which get into food products because of incorrect cultivation of vegetables and fruit, storage, transportation and other reasons. Of the total amount of studies in 2006-2013 in each of the areas, most laboratory studies took place in Samara: in 2007 – 29 % and in 2011 – 21 %; in Toliatti – in 2007 – 29 % and in 2008 – 20 % (Table 1).

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In 2013, we analyzed the data from 9925 studies of food product chemical contamination in Samara conducted in 2010-2012. The ratio of the null values in the sample for each of the three years did not exceed 60% and totaled, on average, 6,1%.

Table 1

The number of studies on chemical contamination of food products in 2006–2013 presented to the FIF[1]

Area	2006	2007	2008	2009	2010	2011	2012	2013
Samara region	3535	15714	8203	5970	5861	9398	7034	6409
Samara	1555	8814	3198	1497	2693	6446	3662	2734
Toliatti	233	2764	1857	1118	866	869	687	1042

Table 2

General information for 2010-2012 about chemical contaminants in food products (based on R 2.1.10.1920-04)

CAS	Substance	*RfD*, mg/kg (reference dose, concentration)*	SFO** (sloping factor)	IARC	EPA
				Cancer effect group	Cancer effect group
50-32-8	Benzo(a)pyrene*	0,0005	7,3	2A	B2
1336-36-3	Polychlorinated biphenyls	None	0,4	2A	B2
118-74-1	Hexachlorbenzene	0,00017	1,6	2B	B2
7440-02-0	Nickel	0,02	None	2B	A
7440-47-3	Chrome	0,005	None	3	A
50-29-3	DDT	0,0005	0,34	2B	B2
7440-38-2	Arsenic	0,0003	1,5	1	A
7440-43-9	Cadmium	0,0005	0,38	1	B1
7439-92-1	Lead	0,0035	0,047	2A	B2
7439-97-6	Mercury	0,0003	None	None	None
14797-55-8	Nitrates	1,6	None	None	None

N o t e: carcinogens are highlighted in grey.
* – reference level of exposure (dose or concentration) to the chemical substance that is not harmful even in the event of life-long contact (determined based on the maximum dose that has no effect and the minimum dose that has the biological effect under study)
** – sloping factor shows carcinogenic potential which reflects the increase in cancer risk under exposure to the effect dose)
*** – carcinogen classification (IARC): 1 – known human carcinogens; 2A – probable carcinogens; 2Б – possible carcinogens; 3 – agents that are not classified by cancer activity; 4 – agents that probably bear no cancer hazard for humans.

The following food products appeared to be on the priority list based on the average number of studies (availability of information): milk and milk products, vegetable oil and other faits, meat and meat products (100-75%) followed by (in the descending order) sugar and confectionery, fish and fish products, vegetables and the gourds, bread and bread products, potatoes, fruits and berries The actual volume of available data did not contradict the recommended volumes (recommended number of samples).

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[1] Federal Information Foundation

[2] Regional Information Foundation

Table 2 shows general information about chemical contaminants in food products. In the course of a preliminary analysis, we excluded such contaminants as aflatoxin, penicidin, benzo(a)pyrene, T-2-toxin, desoxynivalenol, hexachlorobenzene, zearalenone, 2,4-D-amine salt, 2,4-D-butyl ether, 2,4-D-crotile ether – because the data was collected only over the period of one year (2010) out of the three years of the study. In 2012-2011, the contaminants were not studied or were inconsistent; moreover, they were not included in the list of priority products.

Table [4] includes the groups of products, food product consumption in kilograms per year per person, recommended and actual total and per annum (out of the three years) amount of samples, studies, their average number per period under study and the ranking in accordance with the Guidelines for the Rational Standards of Food Product Consumption that Meets Today's Health Requirements (approved by the RF Department of Public Health and Social Development, Decree №593n of August 2, 2010)

The actual amount of available data did not contradict the recommended volumes (recommended number of samples). In 2012, as compared to 2010-2011, the average concentrations increased: in bread and bread products – of lead, mercury, and DDIT; in vegetables and the gourds – of mercury and arsenic; in meat and meat products – of lead, mercury, and DDT; in milk and dairy products – of arsenic; in fish and fish products – of mercury; in vegetable oil and other fats – of lead and DDT (Table 3).

The calculations of the excess frequency as compared to the maximum permissible concentrations of the average level of priority chemical contaminants in the main food products in Samara for the period of 2010-2012 showed that lead was indentified in 100% of laboratory tests, there was no excess compared to MPC; cadmium was identified in 85% of laboratory test, and it exceeded MPC by 1.028 times in vegetables and the gourds; arsenic – in 100% of laboratory tests, no excess as compared to MPC; DDT - in 98% of laboratory tests, exceeded MPC by 1.13 times, was identified in bread and bread products.

To evaluate the level of exposure, we used the median of contaminant concentration in food products and the 90th percentile (2010-2012) as shown in Table 4. Additionally, we provided the results of the evaluation of exposure to food product contaminants (Table 5). Exposure evaluions and the calculation of the contribution of each of the product groups in the total exposure value was conducted based on the following formulas (1) and (2).

Table 3

Increase (+) in the chemical concentrations in the main food product groups in Samara in 2012 as compared to 2010–2011

Product group	Lead	Mercury	Cadmium	Arsenic	DDT
Bread and bread products	+	+	–	–	+
Potatoes	–	–	–	–	–
Vegetables and the gourds	–	+	–	+	–
Fruits and berries	–	–	–	–	–
Meat and meat products	+	+	–	–	+
Milk and dairy products	–	–	–	+	–
Fish and fish products	–	+	–	–	
Sugar and confectionaries	–	+	–	–	+
Vegetable oil and other fats	+	–	–	–	+

Table 4

Toxic concentrations in the main food products consumed in Samara (2010–2012), mg/kg

Product group	Lead		Mercury		Cadmium		Arsenic		DDT	
	Median	90th percentile	Median	90th percentile	Median	90th percentile	Median	90th percentile	Median	90th percentile
Bread and bread products	0,1	0,1	0,0034	0,005	0,02	0,02	0,008	0,008	0,0113	0,012
Potatoes	0,0334	0,045	0,0072	0,01	0,0118	0,0145	0,025	0,025	0,0061	0,0075
Vegetables and the gourds	0,0511	0,061	0,0039	0,0062	0,0305	0,0407	0,0175	0,0194	0,0053	0,0065
Fruits and berries	0,0087	0,0087	0,0021	0,004	0,01	0,01	0,025	0,025	0,005	0,005
Meat and meat products	0,0841	0,1817	0,0464	0,0088	0,1222	0,025	0,2616	0,0253	0,0311	0,0123
Milk and dairy products	0,08	0,08	0,0166	0,0126	0,0138	0,0239	0,0182	0,0313	0,005	0,005
Fish and fish products	0,1254	0,17	0,02	0,0227	0,01	0,01	0,0244	0,0256	0,005	0,0055
Sugar and confectionaries	0,0393	0,0835	0,0036	0,0057	0,0075	0,01	0,0225	0,025	0,0042	0,0052
Vegetable oil and other fats	0,0291	0,0633	0,0037	0,0043	0,01	0,01	0,0173	0,0244	0,005	0,005

Table 5

Evaluation of exposure to food product contaminants, mg/kg body mass/week

Substance	Exposure evaluate based on	
	medians	90th percentile
Lead	0,01368	0,01697
Mercury	0,00088	0,00194
Cadmium	0,00376	0,00669
Arsenic	0,00376	0,00669
DDT	0,00098	0,00123

Public exposure to food contaminants is calculated based on the formula:

$$E_{\text{xp}} = \frac{\sum_{i=1}^{N} (C_I \cdot M_i)}{BW}, \qquad (1)$$

where Exp – value of exposure to contaminants, mg/kg body weight /day (mg/kg body weight /week, mg/kg body weight); C – contaminant concentration in the i product, mg/kg; M_i^i – consumption of the i product, kg/day (kg/week, kg/year); BW – human body weight, kg (standard value – 70 kg); N – total amount of products included in the study.

Contribution of individual products to the total exposure to food contaminants is based on the formula:

$$C_{ontr} = \frac{C_I \cdot M_i}{\underset{i=1}{\overset{N}{\mathrm{SUM}}}(C_I \cdot M_i)}, \qquad (2)$$

where Contr – contribution of the i product to the total exposure value; C_I – contaminant concentration in the i product, mg/kg; M_i – consumption of the i product, kg/day (kg/week, kg/year). Then we calculated the percent contribution of a product group to the total exposure (Table 6) and the group rankings based on individual contributions in the descending order of contribution.

Table 6

Contribution of food products to the total chemical exposure and individual administration

Product group	Lead		Mercury		Cadmium		Arsenic		DDT	
	contribution, %	administration, mg/kg	contribution, %	administration, mg/kg	contribution, %	administration, mg/kg	contribution, %	administration, mg/kg	contribution, %	administration, mg/kg
Bread and bread products	22	10,6300	11	0,3585	18	2,1260	6	0,8504	19	1,2031
Potatoes	4	2,2000	15	0,4745	6	0,7798	12	1,6475	7	0,4044
Vegetables and the gourds	10	4,8400	12	0,3705	25	2,8882	12	1,6568	8	0,5016
Fruits and berries	1	0,5800	5	0,1411	6	0,6720	13	1,6800	5	0,3360
Meat and meat products	13	6,2900	16	3,4690	10	1,1295	12	1,5772	36	2,2440
Milk and dairy products	41	20,1600	23	3,6514	30	3,4691	34	4,5781	20	1,2600
Fish and fish products	5	2,5300	13	0,4048	2	0,2070	4	0,4924	2	0,1006
Sugar and confectionaries	3	1,3100	4	0,1192	2	0,2505	6	0,7515	2	0,1388
Vegetable oil and other fats	1	0,3100	1	0,0393	1	0,1070	1	0,1856	1	0,0535

According to the reduced calculations, the biggest contributors to the chemical exposure of all the product groups are milk and dairy products, vegetables and the gourds, meat and meat products. Calculations of the hazard quotients for the food products the reflect the ratio of the measured dose of contaminants to the permissible (risk of noncancer effects) showed that in terms of concentrations: lead HQ med = 0,5473 and HQ 90% = 0,6789; mercury concentration HQ med = 0,6007 and HQ 90 % = 0,0614; cadmium concentration HQ med = 0,4653 and HQ 90% = 0,6467; arsenic concentration HQ med =0,2506 and HQ 90% =0,4457; DDT concentration HQ med = 1,9733 and HQ 90% = 2,4619.

By the median values and the 90th percentile, the levels of lead, mercury, cadmium, arsenic did not exceed one; also, exposure was permissible; DDT had a higher value than one which means DDT required additional advanced exposure evaluation. Based on the analysis of DDT concentration in food products, it was determined that the biggest contributors to the exposure associated with this contaminant by the median of its content are bread and confectionaries – 85%; whole milk – 2%; potatoes – 4%; onions, cabbage, carrots, beets, meat, grits, grains, wheat flour, sugar, fruits, and berries – 1% each; based on the 90th percentile of DDT concentration, the biggest contributor is tinned fish – 18% (other products – 4% each). Arsenic is in the group of chemicals which bear cancer risks regardless the type of administration[1].

Table 7

Noncancer risk associated with arsenic exposure in food products (population at large)

Food product groups	Calculated average exposure, mg/kg/day	Hazard quotient (*HQ*)
Bread and bread products	0,000022	0,001
Potatoes	0,000068	0,004
Vegetables and the gourds	0,000048	0,003
Meat and meat products	0,000058	0,004
Milk and dairy products	0,000050	0,003
Fish and fish products	0,000067	0,004
Sugar and confectionaries	0,000062	0,004
Vegetable oil and other fats	0,000048	0,003
Fruits and berries	0,000068	0,005

Table 8

Cancer risk associated with arsenic exposure in food products (population at large)

Affected organs	$(mg/kg/day)^{-1}$	Individual risk (probability)	Population risk (number of cases)
Liver	1	2,4E-04	280
Lungs	2,5	6,0E-04	702
Bladder	2,5	6,0E-04	702
Kidney	0,86	2,0E-04	241
Sking	1,5	3,6E-04	421
All cancer sites	–	20,0E-03	2348

Tables 7 and 8 show the results of evaluation of the noncancer and cancer risks associated with peroral arsenic administration. Arsenic, lead and cadmium have cumulative capabilities and

[1] Sanitary Regulations and Standards 1.2.2353-08 Carcinogenic Factors and General Reguirements to Cancer Prevention.

are among priority food contaminants. Proportional to the increase in the total contribution of the indicated contaminants to the exposure is higher hazard quotient and the risk to affect human organs and systems [1].

The assessment of cancer risks associated with peroral arsenic exposure indicates that the risk is average and that the possibility of a malignant tumor in prospect. Estimated number of malignant tumors in prospect for the studied population provided that the exposure and population size are constant constitute 20 cases per 10 000 population in Samara.

The data on food contamination in Toliatti was processed in 2012 based on the laboratory test for 2006-2011. The study results showed that in Toliatti, milk, buttermilk, lactoserum, liquid fermented milk (1483 tests) contained metals (arsenic, lead, cadmium, mercury – in 97%) at below the permissible levels which was in accordance with the federal guidelines. Milk is known to be a university and irreplaceable product for children and adults. It contains a balanced mix of necessary microelements. Milk is often provided to employees as part of the medical and preventative activities to prevent professional illnesses. Additionally, milk increases the overall functioning of a human body, alleviates the effects of radioactive and other toxic substances at industrial enterprises

However when implementing a nonorganic effect alleviation program, we recommend that you take lactic acid bacteria products (butter milk, sour milk, bifidok, etc.), pectin, (contained in the citruses, apples, radish, beets, and other fruits and vegetables). These products are irreplaceable for the residents of industrial areas since they further the cleansing of a human body from hazardous substances that come from the outside (lead to decreased absorption of toxic chemicals and fast elimination from the body).

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