



# Risk Assessment of Chemical Contaminants Ingestion with Nutrition of Children Aged 3–6 Years Old from the City of Kazan

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† Presented at the 1st International Electronic Conference on Environmental Health Sciences, 15 November–7 December 2018; Available online: <https://iecehs-1.sciforum.net/>.

Published: 14 November 2018

**Abstract:** The analysis of the such chemicals as cadmium (Cd), lead (Pb), arsenic (As), mercury (Hg) intake with the diet of children aged 3-6 years old from the city of Kazan for periods (2007-2010 and 2011-2014) was carried out. The study of actual child nutrition was performed by questionnaire and time-weight methods. The calculation of daily doses was made with the account of regional exposure factors at the 95<sup>th</sup> perc level. The non-carcinogenic risk from the exposure to methylmercury with basic food groups at the level of the 95<sup>th</sup> perc made 3.89 and 3.33 for both periods, 10.67– for arsenic in the first period, being unacceptable (HQ >1). In 2007-2010, the central nervous system (CNS), the hormone system (HS), the immune system (IS), and the development (HI = 15.75, 12.87, 11.72 and 4.03) were exposed to the highest toxic effect. An in 2011-2014, the CNS and the development (HI = 4.02 and 3.98) were. The risk of developing non-carcinogenic effects for these systems (64% - 91 %) was mainly due to contamination of foods with As for the first period, and– to the intake of Pb (46 % - 57%) for the second period. The value of the total individual carcinogenic risk (ICR<sub>Cd, Pb, As</sub>), for the second period (1.69E-05) corresponds to maximum allowable level. In 2007-2010, the total ICR made 2.45E-04, which is an unacceptable level for the population. The major contribution to the total ICR due to the intake of contaminated foods was made by As – 92.55 % in the first period, and by Cd – 79.93 % in the second period.

The peculiarities of the child body (the amount of chemicals ingested per kilogram of the body weight is higher in children than in adults), determine the potential risk and are responsible for high vulnerability on exposure to chemicals and development of adverse effects.

**Keywords:** chemical contaminants; foods; non-carcinogenic and carcinogenic risk assessment; the child population

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## 1. Introduction

Modern data show that exposure to toxic metals remains a serious problem for public health. A considerable number of the population of the Russian Federation and Europe are exposed to Pb, Cd at the level higher than national reference values. Depending on conditions, from 30 to 80% of potentially harmful substances including heavy metals (HM) enter the human body with foods. Entering the human body primarily with foods HM cause disorganization of metabolic processes and functional impairment of the immune and other systems. Moreover, the determination of regional (local) exposure levels with the account of age differences in exposure factors, sensitivity to carcinogens [1] and a complex of ecological factors in the territory under study remains an important aspect [2,3].

## 2. Materials and Methods

We analyzed actual nutritional patterns for children aged between 3 and 6 years, in two basic directions: individual and family dietary patterns (questionnaire method), and dietary patterns in institutions where children are fed according to either full or partial meal plans (time-weight method). The actual nutritional pattern of children in the Municipal Preschool Educational Institution No. 146 in the city of Kazan was identified by analyzing monthly reports on food expenditures (according to cumulative records), as well as selectively according to menu production records. The assessment of children's nutrition was supplemented by the results of a survey of parents through questionnaires related to food intake on weekends and on week day evenings. The assessment of exposure to Hg coming with food was carried out for the period from 2011 to 2014 on the basis of the median and the 95th percentile, in accordance with Guidelines 2.3.7.2519-09 "Exposure determination and risk assessment of the impact of chemical contaminants in food on the population". The non-carcinogenic risk was assessed on the basis of studies of Hg content in food groups, performed at the accredited laboratory of the FSFHI "Center for Hygiene and Epidemiology in the Republic of Tatarstan", according to Guidelines P 2.1.10.1920-04 [4]. A characteristic of the total toxic effects was made based on hazard quotients (HQ) of the studied substances and total hazard indices (HI) for the substances with unidirectional mechanism of action [5]. According to EFSA, the TWI for MeHg should not exceed 1.3 µg/kg of body weight per week [6].

To assess the carcinogenic risk the life time average daily doses (LADD), the factors of carcinogenic potential (S<sub>Fo</sub>) and AD<sub>AF</sub> were used [4].

Officially recommended data on reference (safe) concentrations (RfD) for non-carcinogenic risk on chronic impact on the critical organs and the human body systems were applied as risk assessment criteria of the examined chemical ingested with foods for the health of the adult and child populations (Tab. 1).

**Table 1.** Indices of non-carcinogenic and carcinogenic hazards of examined chemicals ingested via the peroral route.

CAS	Substance	Non-Carcinogenic effect		Carcinogenic Effect		Sources of Data
		RfD mg/kg	Critical Systems and Organs	S <sub>Fo</sub> mg/(kg·24hrs) <sup>-1</sup>	IARC Classification	
7439-92-1	Lead (Pb)	0,035*	The CNS, the nervous system, the blood, development, the reproductive and the hormone systems	8,5e-03	B <sub>2</sub>	P.2.1.10.1920-04* CALEPA
7440-43-9	Cadmium (Cd)	0,001	The kidneys, the hormone system	0,38	B <sub>1</sub>	IRIS P.2.1.10.1920-04
7440-38-2	Arsenic (As)	0,0003	The CNS, the nervous system, the CVS, the immune and the hormone systems, GIT, the skin	1,5	A	IRIS
7439-97-6	Mercury (Hg)	0,0003	The immune system, the kidneys, the CNS, the reproductive and the hormone systems	-	-	P.2.1.10.1920-04; WHO UNEP 2008
	Methylmercury (MeHg)	0.0001	The CNS, the kidneys, the nervous system	-	-	WHO UNEP 2008

### 3. Results and Discussion

The amount of imported products reduced considerably due to imposition of sanctions, and recently local food products gain great importance among the population of the Republic of Tatarstan. The specific gravity of food samples exceeding the hygienic normative in the content of chemical contaminants made 0.5% in 2014 (0.2% in 2013), but at the same time it remains lower than in the Russian Federation on the whole (0.6% in 2013 and 0.7% in 2012).

Our studies showed that for both periods the ingestion of Pb with foods at Me and 95<sup>th</sup> perc levels correspondingly (82.14 % and 85.91 %; 86.77 % and 87.77 %) made a major contribution to the total exposure for adults and children. Cd (16.21 % and 12.47 % at Me level; 10.88 % and 10.04 at the level of 95<sup>th</sup> perc) and As (14,19 % in Me and 34,35 % in 95<sup>th</sup> perc ) ranked second in the total exposure for the period 2007-2010. The exposure value on ingestion of contaminants with foods was found to be 1.44 times higher in Me in the second period, and 1.13 times higher in 95<sup>th</sup> perc in the first period. (Tab. 2).

**Table 2.** Results of exposure (intake) assessment of chemical contaminants with foods.

Contaminants	2007–2010 Years				2011–2014 Years			
	Exposure ( $\mu\text{g (kg/24hrs)}^{-1}\text{day}$ )		%		Exposure ( $\mu\text{g (kg/24hrs)}^{-1}\text{day}$ )		%	
	Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc
Lead	0,00952	0,03329	69,64	51,02	0,01694	0,05072	85,91	87,77
Cadmium	0,00154	0,00710	11,27	10,88	0,00246	0,00580	12,47	10,04
Arsenic	0,00194	0,02241	14,19	34,35	0,00006	0,00008	0,3	0,01
Mercury	0,00055	0,00218	4,02	3,34	0,00016	0,00093	0,81	1,61
Methylmercury	0,00012	0,00027	0,88	0,41	0,00010	0,00033	0,51	0,57
Total	0,01367	0,06525	100	100	0,01972	0,05778	100	100

The major proportion of Pb contribution to the total exposure was made by cereals and bakery goods (21.56 % and 31.63 % at Me level; 24.02 % and 35.02 % at the level of 95<sup>th</sup> perc correspondingly), meat and meat products, poultry and eggs (24.17 % and 30.22 % at Me level; 18.18 % and 22.58 % at the level of 95<sup>th</sup> perc), milk and dairy products (31.14 % and 18.94 % at Me level; 33.78 % and 20.42 % at the level of 95<sup>th</sup> perc) both for children.

The groups of food products, which contribute most to Cd exposure for both periods, are grains, cereals and bakery goods (42,63 % and 17,82 % at Me level and 39,81 % and 40,17 %, at the level of 95<sup>th</sup>perc correspondingly), and for the period 2011 – 2014, milk and dairy products (64.57 % at Me level; and 27.35 % at the level of 95<sup>th</sup>perc correspondingly), as well as cereals and bakery goods (8.93 % and 17.82 % for children at Me level; and 24.34 % and 40.17 %, at the level of 95<sup>th</sup>perc correspondingly). Meat and meat products, poultry meat and eggs (28.78 % and 36.86 % at Me level; 20.73 % and 28.84 % at the level of 95<sup>th</sup>perc correspondingly), cereals and bakery goods (28.52 % and 18.45 % at Me level; and 40.49 % and 42.74 % at the level of 95<sup>th</sup>perc) make the major contribution to Hg exposure. Fish and non-fish (18.55 % and 28.79% at Me level, 10.94 % and 19.80 % at the level of 95<sup>th</sup>perc) ranked second in order of importance of Hg ingestion with food in children.

The major contribution to the total value of exposure As to for the period 2007-2010 for is made by fish and non-fish (83.13% at Me level, 77.44% at the level of 95<sup>th</sup> perc), and for the period 2011 – 2014, milk and dairy products (57.78 % at Me level; and 64.37 % at the level of 95<sup>th</sup> perc), and sugar and confectionery goods (42.22 % at Me level; and 35.63 % at the level of 95<sup>th</sup> perc). In the rest product groups, the content of As was not revealed.

In aquatic ecosystems, mercury transforms into its organic form, methylmercury (MeHg), which is more bioavailable and bioaccumulates in water food chains to reach the highest concentrations at the upper trophic levels. MeHg is the dominant form of mercury found in fish and other seafoods, and it is particularly toxic for the developing nervous system including the brain. According to recommendations of the United Nations Environment Programme (UNEP) and WHO

recalculation of Hg in fish and non-fish to MeHg was made in the year of 2008. It should be noted that inorganic mercury is a food pollutant, but its impact is considered less important because of its less toxicity compared with methylmercury [7-10].

The risk characteristics showed that the levels of non-carcinogenic (HQ) from exposure to Pb, Cd, As and Hg in the years of 2007-2010 (0.039 – 0.260 at Me level), and in the years of 2011-2014 (0.029 – 0.351 at Me level; 0.039 – 0.829 at the level of the 95<sup>th</sup> perc) did not exceed the reference value equal to 1.0. The increased value of the MeHg content in fish and seafoods, at the level of 95<sup>th</sup> perc for children is responsible for an average risk level (HQ = 2.67 – 2.29), and as for As, the risk level is extremely high (HQ = 10,67).

The total hazard indices (HI), calculated on the basis of Me, were below 3.0 (2.68 in the first and 1.19 in the second periods, which indicates an allowable risk. The alarming level of non-carcinogenic risk (HI = 3.81) was determined at the level of 95<sup>th</sup> perc in children in the second period, and in the first period it was extremely high (HI = 15.53).

The examined chemical contaminants (Pb, Cd, As, Hg and MeHg) found in the analyzed groups of foods during the period under study have the potential to cause various harmful effects in the human body [11].

In the period 2007 – 2010, the major contribution to the total hazard index (HI) caused by contamination of all examined foods in Me and 95<sup>th</sup> perc is made by As (34.54 % and 68.72 % correspondingly), and MeHg (46.32 % and 17.2 % correspondingly).

The contribution of Cd, Pb, and Hg ranges from 1.45 % to 9.69 % in Me, and from 0.88% to 6.67 % in 95<sup>th</sup> perc. In the period 2011 – 2014, for the child population, the major contribution to HI in Me and 95<sup>th</sup> perc is made by MeHg (55.65 % and 60.16 % correspondingly) and Cd (29.57 and 21.77% correspondingly), the contribution of As, Pb, and Hg made from 2.4 to 6.57 % in Me and from 1.02 % to 11.61 % in 95<sup>th</sup> perc. Besides, there is an alarming level of non-carcinogenic risk for the genitourinary system (HI = 3.56 – 5.78) and the central nervous system (HI = 3.0 – 7.92) at the level of 95<sup>th</sup> perc in children for both periods. The risk of developing non-carcinogenic effects for the organs of the genitourinary and the central nervous system is primarily due to contamination of foods with MeHg (60.73 and 76.32 % correspondingly) (Tab. 3).

**Table 3.** Risk assessment of lesions in critical organs and body systems of the child population of the city of Kazan on development of non-carcinogenic effects due to chemical contamination of foods.

Critical Organs And Body Systems	Contaminants Determining the Effect	2007 – 2010 years				2011 – 2014 years			
		Hazard Index (HI)		Contribution of Organs and Systems to ΣHI (%)		Hazard Index (HI)		Contribution of Organs and Systems to ΣHI (%)	
		Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc	Me	95 <sup>th</sup> perc
Kidneys	Cd, Hg, MeHg	3,03	5,78	20,32	18,24	1,09	3,56	29,86	29,16
Hormone system	Cd,Pb, As, Hg	1,66	3,93	11,13	12,4	0,53	1,52	14,52	12,45
CNS	Pb, As, Hg, MeHg	3,85	7,92	25,82	24,99	0,84	3,00	23,01	24,57
Nervous system	Pb, As, MeHg	3,71	7,88	24,88	24,87	0,76	2,54	20,82	20,80
CVS	As	1,13	2,93	7,58	9,25	0,03	0,04	0,82	0,33
Blood	Pb	0,04	0,08	0,27	0,25	0,07	0,21	1,92	1,72
Reproductive system	Pb Hg	0,18	0,12	1,21	0,38	0,15	0,65	4,11	5,32
Immune system	As, Hg	1,27	2,97	8,52	9,37	0,11	0,48	3,02	3,93
Development	Pb	0,04	0,08	0,27	0,25	0,07	0,21	1,92	1,72
Total		14,91	31,69	100	100	3,65	12,21	100	100

The examined contaminants (Pb, Cd, As) are potential chemical carcinogens belonging to groups A, B1, B2 according to IARC classification [4]. The results of calculating the individual (ICR) and population (PCR) carcinogenic risks for the population health caused by contamination of foods with Pb, Cd and As are given in Table 4. According to American Environmental Protection Agency (US EPA), carcinogenic risks are on the whole higher on exposures during early life periods compared with similar exposures at older ages. An age-dependent adjustment factor (ADAF), which is equal to 3 at the age from 2 to 16 years old, was used for the quantitative assessment of a carcinogenic potential of chemicals with genotoxic effect (Pb, Cd) [12].

**Table 4.** Indices of carcinogenic risk for the health of the child population due to contamination of foods with chemicals.

Contaminants	Slope factor (SFo)	years	LADD <sub>cyMM</sub>	ICR	PCR	
Pb	0.0085	Me	2007–2010	1,75E-04	1,49E-06	1,0
			2011–2014	3,11E-04	2,64E-06	0,2
		95th pers	2007–2010	6,11E-04	5,20E-06	0,3
			2011–2014	9,31E-04	7,92E-06	0,5
Cd	0,38	Me	2007–2010	2,83E-05	1,07E-05	0,7
			2011–2014	4,51E-05	1,72E-05	1,0
		95th pers	2007–2010	1,30E-04	4,95E-05	3,0
			2011–2014	1,07E-04	4,05E-05	2,5
As	1,5	Me	2007–2010	3,96E-05	5,93E-05	3,7
			2011–2014	3,70E-07	5,56E-07	0,03
		95th pers	2007–2010	4,54E-04	6,80E-04	42,0
			2011–2014	4,99E-07	7,48E-07	0,04

The values of total individual carcinogenic risk (ICR Cd, Pb, As) both in the first (7,16E-05) in Me, and in the second period (2,03E-05 in Me and 4,92E-05 in 95<sup>th</sup> pers) are within the range of allowable values, that is, they correspond to the upper limit of acceptable risk. These levels of individual carcinogenic risk to population are to be constantly controlled. In the period 2007 – 2010,  $\Sigma$  ICR in 95<sup>th</sup> perc made 7,35E-04, which is unacceptable for the whole population and requires carrying out of activities on the risk minimization.

The major contribution to total ICR due to consumption of contaminated foods is made by Cd (82.37 – 89.73 %) and Pb (10.17 – 16.11 %). The value of population carcinogenic risk (PCR Cd, Pb, As) implies the possibility of appearance of upto 3 additional (in addition to the background level of cancer morbidity) cases of malignant neoplasms among the child population.

#### 4. Conclusions

The risk assessment allows narrowing considerably the search on both the effect factors, and probable deterioration of the exposed population's health and save considerable time and money for assembling evidence base confirming the availability of harm to health. The exposure value in children on ingestion of contaminants with foods was found to be 1.44 times higher in Me in the second period, and 1.13 times higher in 95<sup>th</sup> perc in the first period.

Exposure of the child population to environmental contaminants differs significantly from that in adults due to various causes associated with the children's activity, behavior and nutrition, physiological peculiarities of metabolism, permeability of the skin integuments, and etc. The children's response can be modified, but it is practically impossible to predict its degree [13; 14].

The levels of non-carcinogenic risk from the exposure to Pb, Cd, As and Hg for the child population are allowable, because they don't exceed the reference value equal to 1.0. The increased values of MeHg content in fish and seafoods at the level of the 95<sup>th</sup> perc for children are responsible for an average risk level (HQ = 2.67 - 2.29), as for As, the risk level is extremely high (HQ = 10.67).

There is an extremely high level (HI = 15.53) in the first period, and an alarming level of the total non-carcinogenic risk (HI = 3.81) in children at the level of the 95<sup>th</sup> perc. The critical systems exposed to the highest toxic effect in case of simultaneous getting of the examined chemic. The individual carcinogenic risk (ICR) is assessed as negligibly small due to the content of Pb and Cd in foods for the child population. It requires no additional activities on its decrease and is subject to selective periodical control. In the period 2007 – 2010, the value of the total individual carcinogenic risk (ICR, As) is  $7.35E-04$  - 95<sup>th</sup> perc, which is unacceptable for the whole population and requires carrying out of activities on the risk minimization, and is to be constantly controlled.

The results of our studies showed higher risks of exposure of children aged 3-6 years old to the chemicals ingested with foods. The risk assessment is usually associated with uncertainty at the stages of exposure assessment. In our case, we tried to mitigate this aspect, and this fact increased the accuracy and reliability of the risk being assessed. Such exposure factors as the amount of water and various foods consumption should be corrected, when specific regional peculiarities are available. Thus, the regional exposure factors (the body weight), identified in a cross-sectional study of the KFU employees, were used, and the peculiarities of individual and family nutrition at the regional level were taken into account during calculations, because the greater part of the population (up to 95 %) consume locally produced food. The use of age-specific sensitivity to carcinogens with application of ADAF to substances with genotoxic effect allowed performing a correct assessment of carcinogenic risk. The obtained results of carcinogenic risks for adults and children have no strong differences, this fact being possibly related with the absence of data on contamination with As for the period under study. However we showed that on peroral ingestion of chemicals with drinking water the level of carcinogenic risk calculated with the account of ADAF exceeded by a factor of 2-3 the risk levels calculated without age-specific rates of sensitivity to carcinogens [12].

At the same time, the amount of certain HM getting into the human body depends not only on one's consumption of foods containing a specific element, but to a great extent on the quality of one's diet as well. For instance, even insignificant iron deficiency enhances considerably the accumulation of cadmium [11]. According to our data, during the last 10 years, the level of prevalence of anaemia among children from 0 to 14 years old in the city of Kazan made up to 95 % of the class of diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism [7]. The account of regional (local) peculiarities is of great importance during the pollution control of foods, because HM can serve as irreplaceable microelements or as toxicants. Currently, it is the regional risk assessment reflecting the full range and specific peculiarities of the populations under study and accepted exposure scenarios that acquires great importance, which is of great practical importance, when developing risk minimization activities.

**Acknowledgments:** This work was funded by the subsidy allocated to Kazan Federal University for the state assignment in the sphere of scientific activities 19.9777.2017/8.9

**Conflicts of Interest:** The authors declare no conflict of interest

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