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# Methods of assessing the health impacts of chemicals ingested with drinking water

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**Abstract.** Assessment of non-carcinogenic and carcinogenic risks of per oral intake of chemicals with drinking water for children aged 3-6 year old living in 4 districts (zones) of the city of Kazan was carried out. A quantitative characteristic of risk was performed with application of regional exposure factors (REF) at the median level (Me) and the 95-thpercentile (95P). Analysis of the risk data showed that only 5 substances (magnesium, nitrates (in  $\text{NO}_3$ ), fluorides, oil products, and chloroform) made from 62.5% to 89.8% of contribution to total risk value in all zones. General toxic effects for critical organs and systems were due to oil products (from 29 to 54.7%) in the 2<sup>nd</sup> and the 4<sup>th</sup> zones, chloroform (from 10 to 30.6%) and nitrates (from 12.8 to 35.9%) in all zones, magnesium (up to 11.2%) in the 3<sup>rd</sup> zone, and fluorides (from 13.7 to 14.3%) in the 1<sup>st</sup> and the 3<sup>rd</sup> zones. The unacceptable risk level ( $\text{HI}_{\text{me}} = 11.8$  and  $9.9$ ;  $\text{HI}_{95\text{-th Perc}} = 14.8$  and  $12.5$ ) was identified in the 2<sup>nd</sup> and the 4<sup>th</sup> zones with a mixed type of water in the utility and drinking water supply. The ingestion of chemicals with drinking water in different zones of the city of Kazan indicates an alarming and high level of non-carcinogenic and carcinogenic risks for the child population health.

**Keywords:** health risk assessment, exposure factors, drinking water, children.

## Introduction

Monitoring of water ecosystems and water quality comprises an overall ecological assessment of the state and changes of water ecosystems for a variety of major aspects including ecological and sanitary characteristics of the water quality, bioproductivity, the flora and fauna protection, and valuable hydrobiocoenoses, ecological-toxicological and radio-ecological situation [1]. The major trends to increase the effectiveness of using the resources of the multi-purpose water supply reservoirs include optimization of hydrological, hydrochemical and hydrobiological, the provision of water quality in accordance with regulatory requirements of the water users and consumers [2, 3, 4].

The analysis of modern stage of the drinking water quality should take into account and reflect national peculiarities of the drinking water supply within the state and the region. According to the 4-th Guidelines on the drinking water quality of the World Health Organization (WHO) an approach based on risk assessment should be used for justification of management decision on provision of the drinking water safety [5]. The process must include the assessment of both the health risk, and risk management, and encompass all stages of the water supply system: from the water source, the distribution network, to the place of its consumption by humans. The quality of drinking waters depends largely on the quality of natural surface water source (the Volga River), which deteriorated in recent years in the region of the city of Kazan: the water is characterized as “dirty”. Water supply to the citizens of Kazan is carried out from the “Volzhsky” surface intake, the underground water intakes



and the artesian boreholes. The “Volzhsky” water intake provides more than 90% of the city population including the Kirovsky (the 1<sup>st</sup> zone) and Vakhitovsky districts (the 3<sup>rd</sup> zone) with drinking water. The population of the Sovetsky district (the 2<sup>nd</sup> zone) uses drinking water of a mixed character (“Volzhsky” water intake and underground water sources Aki, Azino and Solidarnost). The Privolzhsky (the Volga) district of the city (the 4<sup>th</sup> zone) is provided with mixed water from the water intakes “Mirny”, “Tankodrom”, and “Volzhsky”.

### Materials and methods

The assessment of non-carcinogenic risk on ingestion of chemicals with drinking water was carried out for children aged 3-6 years old living in 4 districts (zones) of the city of Kazan. The selection of research zones was made according to the type of the water supply source in these districts. The assessment of non-carcinogenic risk was performed according to the values of the upper limit of the 95% CI of the results of the research carried out on the basis of an accredited laboratory of the Federal State-Funded Healthcare Institution “The Center of Hygiene and Epidemiology in the Republic of Tatarstan”. The main document in the RF, which regulates the assessment of the population health risk, is “The Guidelines on Human Health Risk Assessment from Environmental Chemicals” P 2.1.10.1920–04 [6]. The study of the contaminant toxicity was carried out on the basis of chronic daily substance intake (per oral route). The characteristic of general toxic effects was performed based on the hazard quotients (HQ) of certain substances and total hazard indices (HI) for substances with unidirectional mechanism of action. The calculation of average daily dose (ADD) of per oral intake of chemicals with drinking water ( $\text{mg}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ) was carried out according to formula 1 [6].

$$\text{ADD} = \frac{(\text{CW}\times\text{V}\times\text{EF}\times\text{ED})}{\text{BW}\times\text{AT}\times 365}, \quad (1)$$

- ADD – average daily dose of ingestion with drinking water ( $\text{mg}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ).
- CW – substance concentration in water, ( $\text{mg}\cdot\text{L}^{-1}$ ).
- V – amount of water intake ( $\text{L}\cdot\text{day}^{-1}$ ).
- EF – exposure frequency, ( $\text{days}\cdot\text{year}^{-1}$ ).
- ED – exposure duration (years).
- BW – body weight (kg).
- AT – averaging exposure time, years (for non-carcinogens,  $\text{AT} = \text{ED} \times 365$  days).

Non-carcinogenic risk was assessed according to hazard quotient (HQ) for each substance with application of the regional exposure factor at the median level (Me) – usual exposure range, and the 95-th percentile ( $P_{95}$ ) – maximum reasonable exposure (formula 2).

$$\text{HQ} = \frac{\text{ADD}}{\text{RfD}}, \quad (2)$$

- RfD – reference dose (safe exposure level) for each of the substances ( $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ) [6]. Total hazard quotients (HI) were calculated according to formula 3.

$$\text{THI} = \sum \text{HQ}, \quad (3)$$

To assess carcinogenic risk, the lifetime average daily doses (LADD), the carcinogenic potential factors (SFo), and age-dependent adjustment factors (ADAF) were used [7]. Regional exposure factors (REF) at the median level (Me) and the level of the 95-th percentile (95P) were determined based on the results of the questionnaire survey of parents, grandmothers and babysitters [8]. Non-carcinogenic and carcinogenic risks were assessed for the regional exposure factor at the median level (Me), (usual

exposure range), and the level of the 95-th percentile (P95, maximum reasonable exposure). The THI values from 1.1 to 3.0 were taken for a tolerable level of non-carcinogenic effects; the range of THI values from 3 to 6 was regarded as an alarming risk level and THI values higher than 6 – as a high one. The TCR value equal to  $1.0 \times 10^{-5}$  was a tolerable risk level for carcinogenic effects [6]. The reference values for calculating the impact (exposure) assessment and non-carcinogenic risk assessment are given in Table 1.

**Table 1** Concentration of chemical compounds in drinking water in the city of Kazan in the zones under study (mg/l)

Chemicals	CAS	Limit of detection	MPC, mg/l	RFD, mg/kg	Upper bound of 95% CI			
					1 <sup>st</sup> zone	2 <sup>nd</sup> zone	3 <sup>rd</sup> zone	4 <sup>th</sup> zone
Aluminum	7429-90-5	0.05	0.2	1	0.373	0.42	0.4	0.58
Barium	7440-39-3	0.01	4	0.2	0.024	0.034	0.045	0.024
Iron	7439-89-6	0.1	0,3	0.3	0.8	1.71	1.9	0.7
Magnesium	7439-95-4	1	50	11	24.3	63.2	85.05	47.4
Nitrates (in NO <sub>3</sub> )	14797-55-8	0.2	45	1.6	9.8	24.93	26	58.79
Nitrites (in NO <sub>2</sub> )	14797-65-0	0.003	3.3	0.1	0.05	0.2	0.4	0.2
Sulphates	7440-43-9	0.0003	0.001	0.0005	0.0007	0.0006	0.0006	-
Cadmium	7439-96-5	0.01	0.1	0.14	-	0.131	-	0.02
Manganese	7439-92-1	0.05	0.01	0.024	0.007	0.0036	0.0076	0.004
Lead		0.01	7	0.6	1.01	0.64	0.92	0.68
Strontium	7440-50-8	0.02	1	0.019	0.021	0.017	0.015	0.028
Copper	7440-66-6	0.2	1	0.04	0.031	0.062	0.09	0.143
Zinc	16984-48-8	200	1.5	0.06	0.296	0.471	0.57	0.384
Oil products (total)		0.005	0.1	0.03	0.0172	1.993	0.1	1.01
Chloroform	67-66-3	0.001	0.1	0.01	0.106	0.119	0.147	0.115

## Results and discussion

The results of non-carcinogenic risk assessment on peroral intake of chemicals with drinking water showed that the value of total risk indicated the alarming and unacceptable risk levels in all zones (Table 2).

**Table 2.** Hazard quotients (HQ) for substances with unidirectional mechanism of action

Substances	Hazard quotient (HQ)							
	1 <sup>st</sup> zone		2 <sup>nd</sup> zone		3 <sup>rd</sup> zone		4 <sup>th</sup> zone	
	Me	95-th Perc	Me	95-th Perc	Me	95-th Perc	Me	95-th Perc
Magnesium	0.21	0.27	0.56	0.70	0.75	0.94	0.42	0.53
Nitrates (in NO <sub>3</sub> )	0.59	0.75	1.51	1.90	1.58	1.98	3.57	4.48
Fluorides	0.48	0.60	0.76	0.96	0.92	1.16	0.62	0.78
Oil products (total)	0.06	0.07	6.45	8.10	0.32	0.41	3.27	4.11
Chloroform	1.03	1.29	1.16	1.45	1.43	1.79	1.12	1.40
HI	4.24	5.33	11.79	14.8	6.69	8.4	10.93	13.7

Analysis of the risk data showed that only 5 substances (magnesium, nitrates (in NO<sub>3</sub>), fluorides, oil products and chloroform) made from 62.5% to 89.8% of contribution to total risk value in all zones. The hazard quotient for the rest of substances made less than 0.5.

The unacceptable level of total risk ( $HI_{Me} = 11.8$  and  $10.93$ ;  $HI_{95-thPerc} = 14.8$  and  $13.7$ ) was identified in the 2<sup>nd</sup> and the 4<sup>th</sup> zones at the median level and the level of the 95-th percentile (Perc) having a mixed source of the drinking water supply. The assessment of values of the total hazard indices calculated on the basis of the regional exposure factors (the median concentration and the 95-

thpercentile (Perc) for the child population of the city of Kazan indicated (excluding the 1<sup>st</sup> zone) the exceedance of the upper limit of the reference level (3.0) for three systems: the blood, the kidneys, and the cardiovascular system (Table 3).

**Table 3.** Total hazard indices (HI) for substances with unidirectional mechanism of action

HI for certain systems	Calculation of HI with application of regional exposure factors (Me)				Calculation of HI with application of regional exposure factors (95% perc)			
	1 <sup>st</sup> zone	2 <sup>nd</sup> zone	3 <sup>rd</sup> zone	4 <sup>th</sup> zone	1 <sup>st</sup> zone	2 <sup>nd</sup> zone	3 <sup>rd</sup> zone	4 <sup>th</sup> zone
HI the blood	2.14	3.63	4.25	5.28	2.68	4.56	5.34	6.63
HI the kidneys	1.25	7.77	1.93	4.42	1.58	9.76	2.42	5.55
HI the CVS	0.63	1.56	1.64	3.60	0.79	1.96	2.06	4.52
THI total	4.24	11.79	6.69	10.93	5.33	14.81	8.40	13.73

The major contribution to development of general toxic effects on the critical organs and systems given in Table 3, is made by oil products (from 29 to 54.7%) in the 2<sup>nd</sup> and the 4<sup>th</sup> zones, chloroform (from 10 to 30.6%) and nitrates (from 12.8 to 35.9%) in all zones, magnesium (up to 11.2%) in the 3<sup>rd</sup> zone, and fluorides (from 13.7 to 14.3%). In the 1<sup>st</sup> and the 3<sup>rd</sup> zones. An unacceptable risk level ( $HI_{Me} = 11.8$  and  $9.9$ ;  $HI_{95-thPerc} = 14.8$  and  $12.5$ ) was identified in the 2<sup>nd</sup> and the 4<sup>th</sup> zones with mixed type of water in the utility and drinking water supply. The assessment of carcinogenic risk was carried out for 3 substances belonging, in accordance with IARC classification, to group 1 – the carcinogens known to man (cadmium), to group 2A – possible carcinogens (lead) and to group 2B – possible carcinogens (chloroform), which are found in drinking water (Table 4) [7, 9].

**Table 4.** Total carcinogenic risk (TCR) for the child population health on exposure to carcinogens in drinking water

Substance	SFo	CR, (Me)				CR, (95% perc)			
		1 <sup>st</sup> zone	2 <sup>nd</sup> zone	3 <sup>rd</sup> zone	4 <sup>th</sup> zone	1 <sup>st</sup> zone	2 <sup>nd</sup> zone	3 <sup>rd</sup> zone	4 <sup>th</sup> zone
Cd	0.38	6.7E-06	5.69E-06	5.69E-06	0	8.34E-06	7.15E-06	7.15E-06	0
Pb	0.047	8.2E-06	4.2E-06	8.9E-06	4.7E-06	1.03E-05	5.3E-06	1.2E-05	5.9E-06
(CHCl <sub>3</sub> )	0.0061	5.4E-06	6.04E-06	7.46E-06	5.8E-06	6.76E-06	7.59E-06	9.37E-06	7.33E-06
TCR		2.0E-05	1.6E-05	2.21E-05	1.1E-05	2.54E-05	2.0E-05	2.78E-05	1.3E-05

The highest carcinogenic risk level was registered in the 1<sup>st</sup> and the 3<sup>rd</sup> zones at the level of the 95 Perc. The value of TCR on exposure to carcinogens in water was tolerable only in the 4<sup>th</sup> zone. Analysis of risk levels with application of local factor and age differences on exposure to chemicals ingested per orally with drinking water showed that the values of total carcinogenic risk (TCR) on exposure to three drinking water carcinogens – cadmium, lead and chloroform calculated with the account of ADAF exceeded the recommended risk levels in the 1-3 zones.

## Conclusions

In our opinion, the ingestion of oil products is associated with pollution of the surface water supply source (the Volga River) and requires the detailed study. The researchers of the Kazan Federal University showed that the pollution of waters with suspended solid sand oil products was due to effluents from industrial and public utility enterprises, and the surface runoff from the urbanized territory [3, 4, 10]. A high proportion of unsatisfactory samples of iron, nitrates, fluorides, oil products and chloroform is responsible for development of non-carcinogenic effects on the kidneys, the cardiovascular system and the blood system and unacceptable carcinogenic risk for the child population health.

Both in Russia, and in the majority of cases abroad, the projects of risk assessment are, as a rule, of local character, and set a task of predicting the effects of the habitat pollution, which is unfavorable for

the health, within the boundaries of certain cities/towns or districts [7, 10-19]. Such projects allow solving the important problems of risk management at the local level and under the conditions of the city of Kazan.

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