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Results of adolescent health risk assesment on exposure to habitat water peroral factor in conditions of a large industrial city

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Results of adolescent health risk assesment on exposure to habitat water peroral factor in conditions of a large industrial city

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Abstract. Results of the non-carcinogenic risk assessment on ingestion of chemical substances with drinking water showed that the risk value corresponded to the allowable level of the non-carcinogenic risk (HQ < 1) for the major part of elements in all zones. The excess of the allowable level is observed only in oil products in the 1st zone (2.05) and the 4th zone (1.04). However, the total hazard index (HI) on combined peroral ingestion of chemical compounds and elements with drinking water in selected zones of the city of Kazan implies a low risk level for adolescents living in the 1st and the 4th zones (3.7 and 3.59) correspondingly, and is dangerous for health. According to the results of analysis carried out in all zones, the following basic critical organs and systems were identified: blood, CNS, kidneys, endocrine system, cardiovascular system, skeletal system and teeth. The total hazard indices in the 1st and the 4th zones deserve particular attention. The following elements: oil products (29.7% - 54.0%), nitrates (in NO3), chloroform and fluorides make a major contribution to the value of risk. In all other zones, irrespective of the value of exposure factors, total hazard quotients indicate alarming and unacceptable risk levels at HI_{Me} = from 4 to 8.67; and at $HI_{95th\,Perc}$ = from 8.7 to 16.8.

1. Introduction

So far, WHO makes global analysis and assessment of drinking-water hygiene (GLAAS) which is the initiative of the United Nations on water resources. Providing access to safe drinking water is one of the most effective instruments in promoting good health. According to WHO estimates, 58% of global burden of disease (DALY/Disability-adjusted life year) or 842 000 deaths per year are due to unsafe water supplies, water sanitation and hygiene [1].

At present, a large body of research was carried out abroad, on the basis of which national and international data bases of the exposure factor values used when assessing the health risk were formed. The most large-scale data on various exposure factors are available in the guidelines of American Environmental Protection Agency (US EPA) which regularly reviews and corrects them in accordance with the new data obtained via public opinion polls [2-4]. The database of the European Commission contains information on exposure factors for 30 countries of the European Union [5]. As for Russia, the studies on exposure factors were carried out in Moscow, Ryazan, Lipetsk, Novodvinsk and several other cities/towns [6]. Currently, the exposure values recommended in foreign guidelines are available for reference and must certainly be corrected with respect to regional peculiarities. The analysis of

studies on the risk assessment in our country and the Republic of Tatarstan showed the presence of methodological and toxicometric problems resulting in underestimation of the actual health risk level for the child population associated with uncertainties of the exposure assessment, lack of regional and age differences in the factors exposure and susceptibility to carcinogens [7]. WHO underlines in the Guidelines for drinking-water quality that the approach based on the risk assessment should be applied for justification of management decisions on provision of the drinking-water safety [8]. High level of the adolescent morbidity in disease classes related to habitat markers, in particular, implies the necessity for improving the socio-hygienic monitoring in respect of the territory specificity [9]. As of today, one of the priority factors having an effect on health is the quality of the public drinking water supply [10-15]. Health risk assessment for the adolescent population with selection of priority substances and adverse impacts on the adolescent health is an urgent problem.

Objective: to assess the non-carcinogenic and carcinogenic health risks for the adolescent population (aged 12-16 years) on peroral ingestion of chemical substances with drinking tap water on the basis of the regional and standard exposure factors.

2. Materials and methods

The non-carcinogenic risk assessment on ingestion of chemical substances with drinking water was carried out for the adolescents aged 12-16 years, living in 4 districts (1-Vakhitosky, 2-Sovetsky/Soviet, 3-Kirovsky, 4-Privolzhsky/Volga) of the city of Kazan, and that fact allowed minimizing uncertainties associated with specific regional parameters in exposure assessment. The research areas were selected on the basis of arrangement of permanent stations for monitoring the atmospheric air pollution and the children's polyclinics (No. 1, 2, 3, 4) providing services to these districts with the purpose of subsequent complex assessment of the multi-environmental risk. The risk assessment was carried out according to the data of the Regional Information Fund (RIF) of social and hygienic monitoring and 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" in keeping with Guidelines P 2.1.10.1920-04[16].

Non-carcinogenic risk (ingestion route: per os) is assessed by calculating the hazard quotient (HQ). The HI is usually calculated only for the substances having an effect on the same body organs and systems. The approach based on safe (reference) doses and total hazard indices (THI) was used for the non-carcinogenic risk assessment. Life average daily doses (LADD), carcinogenic potential factors (SF) and ADAF were used for assessing the non-carcinogenic risk. Non-carcinogenic and carcinogenic risks were assessed for exposure factors (standard and regional ones) at the median level (Me), (usual exposure range), and the 95th Percentile (P_{95}, maximum rational exposure). The study of the contaminant toxicity was carried out on the basis of chronic daily ingestion of a substance (the peroral route). Characteristics of general toxic effect were identified based on hazard quotients (HQ) of certain substances and hazard indices (HI) for the substances with synergistic effect. Calculation of an average daily dose (ADD) of chemical substances ingested perorally with drinking water was made according to formula 1 [16]:

$$\text{ADD} = \frac{(Cw \times V \times EF \times ED)}{BW \times AT \times 365} \tag{1}$$

where ADD – average daily dose ingested with drinking water (mg·kg^{-1}·day^{-1}); CW – the substance concentration in water, (mg·L^{-1}); V – the amount of water taken, (L·day^{-1}); EF – the exposure frequency, (days·year^{-1}); ED – the exposure duration (years); BW – the body weight (kg); AT - the exposure averaging time, years (for non-carcinogens, AT = ED × 365 days);

$$\Sigma HQ = \frac{ADD}{RfD} \tag{2}$$

where RfD is the reference dose (safe effect level) for each of the substances (µg·kg^{-1}·day^{-1}) [16].

Total hazard quotients (HI) were calculated according to formula 3

$$THI = \Sigma HQ \tag{3}$$

The regional exposure factors investigation was performed in the cross-sectional study. 1560 persons of two age groups: 680 children aged 12-16 years underwent the questionnaire survey. A questionnaire including the assessment parameters of regional exposure factors (EF) was developed by the researchers of the Institute of Fundamental Medicine and Biology under Kazan (Volga Region) Federal University. Owing to the fact that distribution of the quantitative EF was statistically significantly different from normal distribution, the median (Me) and the 95th percentile (Perc) were applied for their presentation. Comparison of the median values of the EF for the child and adult populations was made by means of the Mann –Whitney U criterion (U test). The value of $p < 0.05$ was taken for a critical level of statistical significance.

Statistical analysis of the obtained data was performed with Windows 2007 using standard application program packages Excel 2007 and «STATISTICA».

3. Results

The assessment of the peroral non-carcinogenic risk was carried out in terms of coefficient and hazard indices; critical organs, systems and effects complied with the established reference doses were identified.

We studied the content of 19 priority chemical pollutants including three carcinogens in the drinking water of the city of Kazan for the period from 2010 to 2015. The chlorine residual wasn't mentioned in calculations due to the fact that at present the reference doses are not determined on chronic chloramine ingestion. Owing to the fact that distribution of the values of exposure factor and concentration of pollutants was different from normal distribution, the 95th percentile (Perc) was applied for their presentation. The excess of hygienic regulations was not the major priority criterion. The major criterion was revealing of compounds whose detection rate in drinking water samples exceeded 5% in all the territories under study. The assessment of non-carcinogenic risk on peroral ingestion of chemical substances with drinking water revealed differences in the risk levels at regional values compared with TEF. The results of non-carcinogenic risk assessment on peroral ingestion of chemicals with drinking water showed that the total risk value corresponded to the allowable level only in the 2nd and the 3rd city zones. In all the rest zones, irrespective of the exposure factor values, the total hazard quotients indicate alarming and unacceptable risk levels. An unacceptable total risk level is registered at HI_{Me} = from 4 to 8.67; $HI_{95th\ Perc}$ = from 8,7 to 16.8 is observed in all zones at the median level and the 95-th Percentile (Perc). Total hazard indices calculated at the level of standard EF for the adolescents, apart from the 2nd and the 4th zones (the kidneys – 6.13 and 3.32) and the 1st , 2nd zones (the blood – 3.19 and 3.01), do not exceed the upper borders of the reference level (3.0). The assessment of the total hazard index values calculated on the basis of regional exposure factors (median concentrations and the 95th Percentile (Perc) for the adolescent population of the city of Kazan showed the excess but not of the upper border of the reference level (3.0) for three systems: the blood, the kidneys, the cardiovascular system and the liver (figure 1).
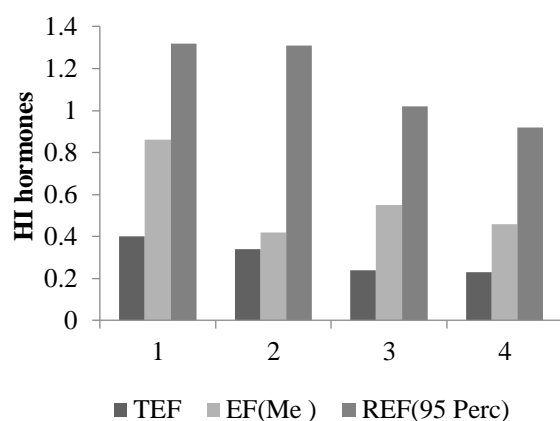

Figure 1. Total hazard indices (HI hormones) for substances with synergistic effect calculated with application of TEF and REF

The values of total hazard indices (HI hormones) of the substances with synergistic effect calculated with application of TEF and REF revealed higher indices in the 1st and the 2nd zones for the adolescent population.

The availability of criteria for subsequent risk assessment – the carcinogenic potential factors on peroral exposure (SFo) was ascertained for chemical carcinogens. Substances belonging to groups 1,2A, 2B according to the IARC and US EPA classification were regarded as potential chemical carcinogens. Carcinogenic risk assessment was carried out for 3 substances contained in drinking water: cadmium, lead and chloroform.

The carcinogenic risk levels for these carcinogenic substances were calculated with application of standard values and regional exposure factors at the level of Me and the 95th perc (table 1).

Table 1. Total carcinogenic risk (TCR) for adolescent health on exposure to carcinogens in drinking-water

TCR	Zones			
	1st	2nd	3rd	4th
REF_{Me}	1. 67 10^{-6}	1.70 10^{-6}	1.05 10^{-6}	1.66 10^{-6}
$REF_{95\,Pers}$	1.49 10^{-5}	1.65 10^{-5}	1.96 10^{-5}	1,46 10^{-5}
TEF	7.44E 10^{-6}	8.23 10^{-6}	9.82 10^{-6}	7.31 10^{-6}
Differences, times:				
REF_{Me} / TEF	0.224	0.207	0.107	0.227
$REF_{95\,Pers}$/ TEF	2.0	2.0	2.0	2.0

Differences in the value of the carcinogenic risk levels made 0.087- 0.323 at EF/TEF, and 2.0 at EF $_{95\,Perc}$/TEF. Chloroform and lead make the major contribution to the value of the carcinogenic risk in all zones. Calculation of the carcinogenic risk levels for these carcinogenic substances was made with the application of correction factors to the carcinogenic potential factor. Chloroform contained in drinking water has no genotoxic effect; therefore, the carcinogenic risk for it was calculated without the application of age coefficients (table 2).

Table 2. Total carcinogenic risk (TCR) for adolescent health on exposure to carcinogens in the drinking water, in respect of correction coefficients (age-dependent adjustment factor - ADAF).

TCR	Zones			
	1st	2nd	3rd	4th
REF_{Me}	2.69 10^{-6}	3.23 10^{-6}	1.53 10^{-6}	3.16 10^{-6}
$REF_{95\,Pers}$	2.54 10^{-5}	3.22 10^{-5}	3.52 10^{-5}	1.96 10^{-5}
TEF	1.27 10^{-5}	1.61 10^{-5}	1.76 10^{-5}	9.80 10^{-6}
Differences, times:				
REF_{Me} / TEF	0.211	0.201	0.087	0.323
REF_{95Pers}/ TEF	2.0	2.0	2.0	2.0

TCR calculated by reference to ADAF exceeded the allowable level from 1.96 in the 2nd zone and by a factor of 1.71 (1.79) in the 1st and the 4th zones at the level of all exposure values. In the 3rd zone, differences are by a factor of 1.34. Comparison of the results of the carcinogenic risk assessment carried out in conformity with the age susceptibility coefficients compared with a traditional approach revealed significant difference in risk levels. TCR calculated with application of the age coefficients exceeds the risk levels obtained without the account of susceptibility of different age groups to carcinogens by a factor of 1.34 – 1.96. The median refers to the 95% quartile upward in the 4th district and downward in the 3rd district. We can suppose that chloroform in the 3rd district and metals in the 4th district make the major contribution in the majority of cases. The highest level of the carcinogenic

risk is determined in all zones under study at 95_{Perc} mark (maximum rational exposure). Non-carcinogenic risk on the chloroform inhalation effect made 5.950637, and carcinogenic risk – 0.000156.

Conclusions

Analysis of the risk levels with application of regional factors and age differences in exposure to chemical substances on peroral ingestion with drinking water showed that the application of standard values in the risk assessment methodology resulted in a two-fold underestimation of actual non-carcinogenic and carcinogenic risks for the adolescent health at the level of the 95-th Percentile (Perc) in all zones. The values of the total carcinogenic risk (TCR) on exposure to three carcinogens in drinking water — cadmium, lead and chloroform calculated with regard to ADAF exceeded the risk levels obtained without considering susceptibility to carcinogens in different age groups by a factor of 1.34/1.71 (1.79) and by a factor of 1.96 (in different zones), irrespective of the applied exposure factor. In all other zones, irrespective of the value of exposure factors, total hazard quotients indicate alarming and unacceptable risk levels at HI_{Me} = from 4 to 8.67; an d at $HI_{95th\ Perc}$ = from 8.7 to 16.8.

Acknowledgements

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