Research Article

Assessment of adolescents' exposure to non-carcinogenic risk associated with drinking water

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ABSTRACT

Aim: The level of the total hazard index (HI) at combined oral intake of chemical compounds and elements with drinking water in the separate zones of Kazan indicates the high and average risk for adolescents residing in zones 1 and 4, respectively, and low risk for adolescents of zones 2 and 3, and poses a hazard to health. The permissible level is exceeded only for oil products in zone 1 (4.1) and zone 4 (1.04), as well as for nitrates (1.13). **Material and Method:** Assessment of non-carcinogenic risk was carried out for adolescents aged 12-16 years living in 4 districts (1 - Vakhitovsky, 2 - Sovetsky, 3 - Kirovsky, and 4 - Privolzhsky), city of Kazan, which allowed to minimize uncertainties associated with specific regional parameters in the evaluation of exposure. **Result and Discussion:** Based on the results of the analysis, the main critical organs and systems were identified in all zones: Blood, central nervous system, kidneys, endocrine system, cardiovascular system, bone system, and teeth. Particular attention should be paid to the indicators of the total HI in zones 1 and 4. They 1.6-3.5 times exceed the levels in other investigated areas. The main contribution to the level of risk is made by the following elements: Petroleum products (29.7-54.0%), nitrates (by NO3), chloroform, and fluorides. **Conclusion:** The greatest hazard to the adolescents in the studied zones of the city of Kazan is the constant presence and intake of chemicals with drinking water. A combined long-term exposure, even within the limits established by hygienic regulations, creates the danger of chemical load on the body and is a risk factor for the health of the adolescents in the city of Kazan.

KEY WORDS: Adolescents, Drinking water, Oral intake, Risk, Risk levels, Target organs

INTRODUCTION

The WHO develops international standards for water quality and human health in the form of guidelines that are used as a basis for regulating and setting standards around the world. The quality of centralized drinking water is one of the most important environmental factors affecting the health of the population, and in particular, adolescents. The problem of sensitivity to the action of environmental factors is relevant, and the children's population, in particular, adolescents, can serve as an indicator of ecological well-being.[1]

To date, it is extremely important to conduct risk assessment activities with the development of methods for the formation of the evidence base for the implementation of health risks in the form of health affection (through epidemiological or in-depth medical and biological research). Currently, solving the problem of hygienic assessment of drinking water quality is impossible without scientific justification and assessment of its harmlessness based on the methodology for assessing the risk to public health. We can determine the contribution shares of the routes of exposure and specific hazards and identify specific sources and causes of pollution.

Adolescence is associated with the strain of all systems of the body in general and can have an increased susceptibility to the impact of various environmental factors, and in particular, pollution of drinking water.

The objective of this paper is to assess the non-carcinogenic risk for the adolescent population health (12-16 years) at oral intake of chemical compounds with drinking tap water using regional exposure factors.

MATERIALS AND METHODS

Assessment of non-carcinogenic risk was carried out for adolescents aged 12-16 years living

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in 4 districts (1 - Vakhitovsky, 2 - Sovetsky, 3 - Kirovsky, and 4 - Privolzhsky), city of Kazan, which allowed to minimize uncertainties associated with specific regional parameters in the evaluation of exposure. The selection of study areas was carried out on the basis of the location of the permanent air pollution observation posts and the children's polyclinics serving these areas (No. 1, 2, 3, and 4) for the purpose of the subsequent complex assessment of multisided risk. The risk assessment was carried out according to the data of the Regional Information Fund 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.[2,3]

HQ values in the range from 0.11 to 1.0 and HI in the range from 1.1 to 3.0 were taken as a permissible level of non-carcinogenic effects. Information on local factors of exposure was obtained in a transverse study with a questionnaire survey of 930 adolescents aged 13-15 years. The questionnaire developed by the staff of the Institute of Fundamental Medicine and Biology of Kazan (Volga region) Federal University included the following information on the exposure factors: Body weight of the child (kg), height (cm), amount of drinking water consumed (l/day), number of water procedures (washing of hands) - times/day, shower (bath) - times/week, duration of water procedures (min/day), duration of exposure (days/year), time spent outdoor (hours/day), and time spent indoor (hours/day). A standard formula was used to calculate the average daily dose and regional exposure values for oral intake of chemicals with drinking water:

$I=(C_W*V*EF*ED)/(BW*AT*365)$,

Where C_W is the concentration of the substance in water mg/L, V - water consumption in l/day, EF - frequency of exposure days/year, ED - duration of exposure, years, BW - body weight, kg, and AT - exposure averaging period, years.

Non-carcinogenic risk (route of entry: Per os) is estimated by calculating the hazard quotient (HQ):

$HQ = I/RfD$,

Where I is the average daily dose of the substance at oral intake, mg/kg, and RfD is the reference (safe) dose.

To assess the total chemical exposure, the total hazard index (HI) is applied as follows:

$HI = HQ_1 + HQ_2 +.... + HQn$,

Where HQq, HQ2, and HQn are the hazard quotients of 1, 2,… n^{th} chemical substances. The calculation of HI is usually carried out only for substances that affect the same organs and body systems.

The statistical analysis of the obtained data is conducted using Windows 2007, with standard application packages Excel 2007 and "STATISTICA v.6.0."

RESULTS AND DISCUSSION

The water supply to Kazan residents is provided from "Volzhsky" surface water field, underground water fields, and artesian wells. "Volzhsky" water field provides drinking water to 80% of the city's population, including Kirovsky (zone 3) and Vakhitovsky districts (zone 1). The population of the Sovetsky district (zone 2) uses mixed drinking water ("Volzsky" water field and Aki, Azino, and Solidarnost underground water sources). Privolzhsky district of the city (zone 4) is provided with mixed water from "Mirny," "Tankodrom," and "Volzhsky" water fields. As a result of the analysis, it was established that average concentrations of chemical elements in different zones of the city do not exceed the levels set in hygienic regulations (maximum permissible concentration) although they fluctuate widely. In our opinion, this is due to both connection with underground and surface sources of water supply and a different degree of wear of the distribution pipelines. The composition of drinking water affects the formation of a total risk to the health of the population and contributes to an increased incidence of the population.[4-6] The concentrations of chlorides, sulfates, fluorides, and phosphates in the investigated zones had no statistically significant differences (Table 1).

The results obtained in the transverse study showed that adolescents, on average, at the level of the 95^{th} percentile (Perce), consume 3.0 L/day, which exceeded the corresponding value of the standard exposure factor for adults. The body weight in adolescents at the level of Me was 62.2 kg, and at the level of the upper 95^{th} percentile (Perc), it exceeded the standard value by 2.1 kg.

Analysis of an average content of certain metals (HM) in the sources of the central water supply of the city of Kazan for the period from 2010 to 2015 revealed significant differences between them in the content of zinc and magnesium, which were above the standards in the underground water sources.[7]

The composition of drinking water affects the formation of a total risk to the health of the population and contributes to an increased incidence of the population.[8-10] Sixteen pollutants made the list of

priority substances entering the organisms with drinking water, aluminum, barium, iron, calcium, magnesium, nitrates (NO_3), nitrites (NO_2), cadmium, manganese, lead, strontium (stable), copper, zinc, fluorides, residual chlorine, petroleum products (total), and chloroform. The main criteria for the selection of priority chemical compounds were a high proportion of unsatisfactory samples in hygienic studies, known reference doses (RfD), known critical target organs, and known coefficients and other reference values necessary for calculations (Table 2).

The results of the assessment of non-carcinogenic risk from the chemicals supplied with drinking water showed that the highest level of the total HI (HI = 7.5 and 3.5) is observed in the zone of Vakhitovskiy (zone 1) and Privolzhsky districts (zone 4) (Figure 1).

The main contribution to the risk level in zone 1 is made by: Petroleum products - 54%, nitrates (NO_3) - 12.8%, chloroform - 9.8%, fluorides - 6.4%, magnesium - 4.7%, and iron - 4.7% of the total risk. The second place by the level of risk belongs to zone 4, where the main share of the risk level is also determined by nitrites (NO_3) - 32%, petroleum products - 29.7%, chloroform - 13.2%, chlorine - 9.1%, and fluorides - 5, 6%. This trend is typical for other zones of the city: Chloroform, fluorides, nitrates, iron, and petroleum products account for 67.4-73.1% of the total risk. In accordance with the criteria for the risk levels, most of the analyzed chemicals supplied with drinking tap water in almost all zones, have a minimum level of risk (HQ < 0.1). Analysis of the combined supply of chemicals with drinking water has shown that the main impact on and risk to the target organs is caused by

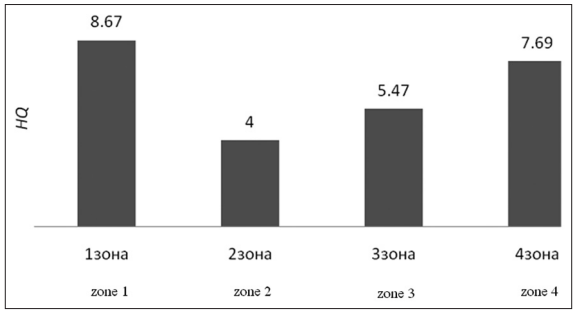

Figure 1: Total hazard index using the regional exposure factor (95%Pers)

Table 1: Average concentrations of chemicals in drinking water in Kazan (mg/l)

Substance	MPC, mg/L (SanPiN 2.1.4.1074-01)	Zones (M ± m)			
		Zone 1	Zone 2	Zone 3	Zone 4
Sr	7.0	0.110±0.007	0.209±0.007	0.105±0.28	0.170±0.017
Cu	1.0	0.0015±0.0015	0.0022±0.0003	0.0015±0.0002	0.0016±0.004
Pb	0.03	0.013±0.0012	0.012±0.0009	0.016±0.0042	0.013±0.0022
Zn	5.0	0.017±0.0016	0.019±0.0019	0.017±0.0035	0.030±0.0079
Cr $^{(6+)}$	0.05	0.0035±0.0014	0.0021±0.0002	0.0026±0.0016	0.0043±0.0018
Fe	0.3	0.079±0.006	0.107±0.0046	0.099±0.018	0.084±0.19
Nitrites	0.1	0.0034±0.0005	0.004±0.0008	0.0036±0.0007	0.004±0.0004
Nitrates	45.0	1.03±0.08	0.97±0.09	0.92±0.07	1.05±0.08
Sulfates	500.0	86±9	84±9	87.2±9.6	83.4±9.2
Fluorides	0.06	0.24±0.015	0.24±0.011	0.24±0.011	0.24±0.013
Cl	0.1	22.0±1.76	22.2±1.67	24.2±1.58	21.8±1.81
Phosphates	-	0.051±0.0044	0.049±0.0043	0.048±0.0052	0.043±0.0055

MPC: Maximum permissible concentration

Table 2: Adolescent health hazard quotients

Substance	HQ in the separate zones of the city			
	Zone 1	Zone 2	Zone 3	Zone 4
Al	0.025983	0.023076	0.012373	0.017941
Ba	0.030049	0.021211	0.019885	0.010605
Fe	0.352629	0.164973	0.195905	0.072176
Mg	0.355441	0.068332	0.239164	0.13329
Nitrates (NO_3)	0.963931	0.189461	0.502651	1.136572
Nitrites (NO_2)	0.12373	0.015466	0.12373	0.061865
Cd	0.074238	0.043305	0.037119	0
Mn	0.057888	0	0	0.004419
PbW	0.063632	0.061865	0.067167	0.035351
Sr	0.065989	0.05207	0.04743	0.035057
Cu	0.055353	0.034188	0.02442	0.045585
Zn	0.012785	0.003196	0.00928	0.014744
Fluorides	0.485639	0.1526	0.293858	0.197967
Cl	0	0.281485	0	0.318604
Petroleum products	4.109884	0.017735	0.103108	1.04139
Chloroform	0.736191	0.327883	0.454706	0.463986
HI	7.513361	1.456846	2.130796	3.59

HI: Hazard index, HQ: Hazard quotient

Table 3: Critical organs and systems as per the results of the assessment of non-carcinogenic risk from the chemicals supplied with drinking water

Critical organs/ systems	HQ using the regional exposure factors (95% Pers)			
	Zone 1	Zone 2	Zone 3	Zone 4
CNS	0.86	0.40	0.46	0.70
Blood	0.98	0.54	1.27	1.72
Kidneys	0.73	0.39	0.16	1.6
Hormonal system	0.86	0.42	0.55	0.46
CVS	1.11	0.21	0.64	1.20
Immune system	0.35	0.16	0.19	0.07
Liver	0.73	0.34	0.02	0.45
Skeletal system	0.54	0.20	0.33	0.23
Mucous membranes	0.86	0.16	0.19	0.07
Gastrointestinal tract	0.05	0.03	0.02	0.04
Skin	0.35	0.16	0.19	0.07
Biochemical indicators	0.06	0.06	0.06	0.04
Endocrine system	0.55	0.42	0.86	0.49
Teeth	0.27	0.27	0.27	0.27
Reproductive organs	0.37	0.24	0.26	0.28
HI	8.67	4	5.47	7.69

HI: Hazard index, CNS: Central nervous system, CVS: Cardiovascular system

the toxic effects of chloroform (liver, kidney, central nervous system [CNS], hormonal system, and blood), petroleum products (kidneys), fluorides (teeth and bone system), and nitrates (blood and cardiovascular system [CVS]), and iron (mucous membranes, skin, blood, and immune system) (Table 3).

The highest total risk level was determined in zones 1 and 4 with a total hazard ratio HI 8.67 and 7.69, which meets the criteria of a high and alarming level.[11] The ranking by risk and the percentage distribution of the obtained data demonstrate that the main critical organs and systems are as follows: Blood (12.1-28.2%), CNS (10.09-10.6%), kidneys (3.5-23.07%), endocrine system (7.0-125%), CVS (6.29-17.3%), skeletal system (6.6-7.3%), and teeth (2.7-6.4%), whereas biochemical indicators, development, and reproductive system correspond to the risk level within the limits of HI values from 0.50 to 1.8.

SUMMARY

The results of the assessment of non-carcinogenic risk from the chemicals supplied with drinking water showed that for most elements the risk level in all zones corresponds to the allowable level of non-carcinogenic risk (HQ < 1). The permissible level is exceeded only for oil products in zone 1 (4.1) and zone 4 (1.04), as well as for nitrates (1.13). However, the level of the total HI at combined oral intake of chemical compounds and elements with drinking water in the separate zones of Kazan indicates the high and average risk for adolescents residing in zones 1 and 4, respectively, and low risk for adolescents of zones 2 and 3, and poses a hazard to health. Based on the results of the analysis, the main critical organs and systems were identified in all zones: Blood, CNS, kidneys, endocrine system, CVS, bone system, and teeth.

CONCLUSION

Based on the results of the study, particular attention should be paid to the indicators of the total HI in zones 1 and 4. They 1.6-3.5 times exceed the levels in other investigated areas. The main contribution to the level of risk is made by the following elements: Petroleum products (29.7-54.0%), nitrates (NO_3), chloroform, and fluorides. The greatest hazard to the adolescents in the studied zones of the city of Kazan is the constant presence and intake of chemicals with drinking water. A combined long-term exposure, even within the limits established by hygienic regulations, creates the danger of chemical load on the body and is a risk factor for the health of the adolescents in the city of Kazan.

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