Health risk assessment of children's population on the delivery of metals with drinking water

Yu A Tunakova¹, A R Galimova¹, V S Valiev²

¹Department of General Chemistry and Ecology, Kazan National Research Technical University named after A. N. Tupolev (KNRTU–KAI), K. Marx, 10, Kazan, 420111, Russia
²Institute for Environmental Problems and Subsoil Use of the Academy of Sciences of Tatarstan, biogeochemistry laboratories, Daurskaya, 28, Kazan, 420008, Russia

E-mail: juliaprof@mail.ru

Abstract. In the work, we assessed the carcinogenic risk to the health of the child population when drinking tap water is consumed in the city based on the calculation of the risk to public health taking into account regional exposure factors. For this, a retrospective study of the quality indicators of drinking water in the city of Kazan at the final consumption point (houses and apartments) in the city was carried out. The calculation results showed that when using regional exposure factors that reflect the specific characteristics of the studied population, the carcinogenic risk values increase by 45%. The use of regional values of exposure factors, which are characteristic of a particular population, increases the accuracy and reliability of risk assessment. It was shown that the carcinogenic risk to health from drinking tap water by children 3-6 years old calculated by regional values of exposure factors in a number of zones exceeds the value recommended by WHO by more than 2 times, which requires the use of effective methods of purification of drinking water from ions that are carcinogenic potential.

1. Introduction

The introduction of the practice of risk assessment in the conditions of constant intake of pollutants allows quantifying the possible toxic effects on the health of the exposed population, which is described in detail in [1-6] (Avaliani, 2013; Novikov, 2016; Rakhmanin, 2005; Revich, 2004; Fridman, 2017; Fights, 2019). The results of the risk assessment can be used to determine the effectiveness of measures to eliminate the impact of negative environmental factors, which increases the importance of an adequate quantitative risk assessment.

To date, SanPiN 2.1.4.1074-01 [7] has been adopted as the main document in Russia. It establishes hygiene requirements for water. A significant number of standards in this document are established by the general sanitary or organoleptic hazard indicators (about 68% of substances) and they do not characterize the direct toxic effect on public health. Also, quantitative doses of a substance are not taken into account, taking into account the actual duration and frequency of exposure, there is no accounting for uncertainties associated with specific exposure conditions. Therefore, even the observed hygienic standard does not ensure safety for public health, since the effect of any toxic substance on the human body leads to potential danger, and increases the likelihood of diseases according to various nosologies [8].
Today, monitoring the content of heavy metals in food and drinking water and assessing the risk of their impact on public health is especially relevant and timely in connection with the widespread distribution of heavy metals in the environment [9-11].

The factors used in calculating exposures and risks should reflect the specific features of the populations studied and should be based on the results of special regional studies. Numerous studies have been conducted abroad, on the basis of which national and international databases of exposure factor values have been created, used in assessing health risks. Within the framework of the project “European Database on Factors Affecting the Exposure of Chemical Pollutants”, which was launched in 2002-2006, a database of exposure factors was created for 30 EU countries [12-14].

Purpose of work: assessment of the degree of chemical safety of drinking water based on the calculation of the health risk of a sensitive population, taking into account regional exposure factors.

2. Materials and methods.
A retrospective study of the quality indicators of drinking water in the city of Kazan at the final consumption point (houses and apartments) in the city for the period from 2012 to 2018 was carried out. To determine the quality of drinking tap water consumed, samples were taken in 11 service areas of children's clinics. The division of the city into areas by zones is intended, in the future, to facilitate the task of bringing the developed recommendations on the purification of drinking water to the public. Children are a kind of “indicator group”, reflecting the reaction of the population to the negative impact of environmental factors. Due to physiological characteristics, children are more sensitive to the quality of their environment, including the quality of drinking water consumed, and the terms for manifesting adverse effects are shorter. In addition, children are less likely than adults to be subject to intra-urban migration; they are more closely tied to the territory in which they live and study [15].

In this work, the quality of drinking water was determined by the content of cations of metals such as (Pb^{2+}, Cu^{2+}, Zn^{2+}, Cr_{(total)}, Sr^{2+}, Fe_{(total)}) and anions (NO_2^-, NO_3^-, SO_4^{2-}, F^-, Cl^-, PO_4^{3-}). Determination of the concentration of metal cations was carried out by atomic absorption spectrometry (AAS). This method is especially convenient for analyzing solutions, since in this case the dissociation of the analyte molecules into atoms can be achieved thermally in the flame of a gas burner. As an analytical method for determining anions, the method of ion chromatography was used. Statistical processing of the results was carried out using the statistical package "STATISTICAv.6.0".

The non-carcinogenic and carcinogenic risks to the health of children were assessed on the basis of the methods described in manual P 2.1.10.1920-04 [16], which uses reference dose values that are an individual characteristic of each substance (threshold calculation model). A non-threshold risk assessment model was also used according to the standard methodological recommendation MP 2.1.4.0032-11 [17]. The hazard coefficient HQ was determined by comparing the values of the potential daily dose of a substance supplied by the oral route and the level of safe exposure for the same route of administration. If the calculated hazard coefficient (HQ) of the substance did not exceed unity, then the effect was assessed as permissible. The hazard index (HI), which is a characteristic of the risk of developing non-carcinogenic effects when combined and complex exposure to chemical compounds for the conditions of simultaneous intake of several substances in the same way, was calculated as the sum of the hazard coefficients for the individual components of the mixture of acting ions.

The carcinogenic risk of drinking water consumption of the established cationic anionic composition was assessed in relation to the sensitive representatives of the urban ecosystem system — the child population — according to the regulated methodology [16]. When assessing carcinogenic risk, a non-threshold model was used in which the obtained risk value showed the likelihood of developing cancer with given dose levels (individual risk).
3. Results and discussions

As a result of statistical processing of the analysis results, it was found that the concentration of metal cations in different research zones varies widely, which is due to both different sources of water supply (surface and underground), and varying degrees of wear and corrosion of specific water mains [18].

The assessment of regional values of exposure factors was performed in the work [19-20] by questioning parents of 1250 children (from 3 to 6 years old).

At the exposure assessment stage, it was found that the calculated doses, with chronic oral administration of the analyzed ions with drinking water, do not exceed the reference levels (RFD) for the children's population. The probability of a child developing harmful effects with the daily intake of the analyzed ions during life is insignificant and this effect is characterized as permissible [20].

Among the studied ions, lead (II) and chromium (VI) ions have a carcinogenic effect.

The received doses of the intake of carcinogenic metals with drinking water for children under 6 years of age according to the standard values of exposure factors and carcinogenic risk values are presented in table 1.

| Zone | Dose (Pb) | Dose (Cr) | Risk (Pb) | Risk (Cr) | Risk |
|------|-----------|-----------|-----------|-----------|------|
| 1    | 0.066     | 0.003     | 3.1·10⁻⁶  | 1.4·10⁻⁶  | 4.5·10⁻⁶ |
| 2    | 0.082     | 0.025     | 3.9·10⁻⁶  | 1.0·10⁻⁵  | 1.4·10⁻⁵ |
| 3    | 0.066     | 0.012     | 3.1·10⁻⁶  | 4.8·10⁻⁶  | 7.9·10⁻⁶ |
| 4    | 0.071     | 0.019     | 3.3·10⁻⁶  | 8.1·10⁻⁶  | 1.1·10⁻⁵ |
| 5    | 0.077     | 0.012     | 3.6·10⁻⁶  | 4.8·10⁻⁶  | 8.4·10⁻⁶ |
| 6    | 0.066     | 0.012     | 3.1·10⁻⁶  | 4.8·10⁻⁶  | 7.9·10⁻⁶ |
| 7    | 0.071     | 0.004     | 3.3·10⁻⁶  | 1.8·10⁻⁶  | 5.2·10⁻⁶ |
| 8    | 0.099     | 0.026     | 4.6·10⁻⁶  | 1.1·10⁻⁵  | 1.5·10⁻⁵ |
| 9    | 0.066     | 0.007     | 3.1·10⁻⁶  | 2.8·10⁻⁶  | 5.9·10⁻⁶ |
| 10   | 0.088     | 0.014     | 4.1·10⁻⁶  | 6.0·10⁻⁶  | 1.0·10⁻⁵ |
| 11   | 0.071     | 0.024     | 3.3·10⁻⁶  | 9.9·10⁻⁶  | 1.3·10⁻⁵ |

The received doses of the intake of carcinogenic metals with drinking water for children 3-6 years of age by the average values of regional exposure factors and carcinogenic risk values are presented in table 2.

The calculation results showed that when using regional exposure factors that reflect the specific characteristics of the studied population, the risk value increases by 45%. The use of regional values of exposure factors, which are characteristic of a particular population, increases the accuracy and reliability of the estimated risk.

According to the WHO recommendations for drinking water, a value of 1 · 10⁻⁵ is used as an acceptable value of a carcinogenic risk [17]. Acceptable risk implies that its level is insignificant in relation to the risks of everyday activities and does not require additional measures to reduce it. Thus, the calculation results showed that the carcinogenic health risk from the use of tap water by children 3-6 years of age, calculated according to the regional values of the exposure factors, in zones 1, 7 and 9 does not exceed the acceptable carcinogenic risk for drinking water recommended by WHO. In zones 3, 5, 6, acceptable risk values are exceeded by 15-23%. In zones 4, 10 and 11 there is an excess of acceptable risk by 47-93%. The maximum excess of values is observed in zones 2 and 8, in which the acceptable value is exceeded by more than 2 times.
4. Conclusions

The use of regional exposure factors, reflecting the specific features of the studied population, increases the risk by 45%. Thus, when assessing water safety and modernizing water treatment systems, it is necessary to use regional values of exposure factors that are characteristic of a particular population, which increases the accuracy and reliability of the estimated risk.

Table 2. Doses of metal intake with drinking water, mcg / (kg • day) and carcinogenic risk to public health according to regional exposure factors.

| Zone | Dose (Pb) | Dose (Cr) | Risk (Pb) | Risk (Cr) | Risk |
|------|-----------|-----------|-----------|-----------|------|
| 1    | 0,096     | 0,005     | 4,5·10^{-6} | 2,0·10^{-6} | 6,5·10^{-6} |
| 2    | 0,120     | 0,036     | 5,6·10^{-6} | 1,5·10^{-5} | 2,1·10^{-5} |
| 3    | 0,096     | 0,017     | 4,5·10^{-6} | 7,0·10^{-6} | 1,2·10^{-5} |
| 4    | 0,104     | 0,028     | 4,9·10^{-6} | 1,2·10^{-5} | 1,7·10^{-5} |
| 5    | 0,112     | 0,017     | 5,3·10^{-6} | 7,0·10^{-6} | 1,2·10^{-5} |
| 6    | 0,096     | 0,017     | 4,5·10^{-6} | 7,0·10^{-6} | 1,2·10^{-5} |
| 7    | 0,104     | 0,006     | 4,9·10^{-6} | 2,7·10^{-6} | 7,6·10^{-6} |
| 8    | 0,144     | 0,038     | 6,8·10^{-6} | 1,6·10^{-5} | 2,3·10^{-5} |
| 9    | 0,096     | 0,010     | 4,5·10^{-6} | 4,0·10^{-6} | 8,5·10^{-6} |
| 10   | 0,128     | 0,021     | 6,0·10^{-6} | 8,7·10^{-6} | 1,5·10^{-5} |
| 11   | 0,104     | 0,034     | 4,9·10^{-6} | 1,4·10^{-5} | 1,9·10^{-5} |

For areas with an excess of acceptable carcinogenic risk, the use of effective methods for the purification of drinking water from ions with carcinogenic potential is recommended.

Thus, risk assessment allows the development of more flexible and adequate targeted recommendations for the protection of the child population when drinking water of unsatisfactory quality. The results of the risk assessment for children's health can be used to determine the necessary degree of post-treatment of drinking water and the reasonable choice of special household systems for post-treatment of water directly at the final consumption point.

References

[1] Avaliani S L, Bezpalko L E, Bobkova T E and Misha A L 2013 Hygiene and sanitation 1 33–5
[2] Novikov S M, Fokin M V and Unguryanu T N 2016 Hygiene and sanitation 8 711–6
[3] Rakhmanin Yu A, Novikov S M and Ivanov S I 2005 Hygiene and sanitation 2 7–10
[4] Revich B A, Avaliani S L and Tikhonova G I 2004 Ecological Epidemiology (Moscow: Publishing Center "Academy") p 384
[5] Fridman K B, Novikova Yu A and Belkin A S 2017 Hygiene and sanitation 7 pp 686–9
[6] Boev V M, Kryazheva E A, Runner D N, Borschuk E L and Kryazhev D A 2019 Health Risk Analysis 2 35–43
[7] SanPiN 2.1.4.1074-01 2001 Drinking Water. Hygienic Requirements for Water Quality of Centralized Drinking Water Supply Systems. Quality Control. Hygienic Requirements for Ensuring the Safety of Hot Water Supply Systems (as amended on April 2, 2018) (CODE: electronic fund of legal and regulatory documentation)
[8] Zhizhin K S, Trushkova E A and Omelchenko E V 2016 International Journal of Experimental Education 11-1 88–90
[9] Rakitsky V N, Avaliani S L, Shashiya T A and Dodina N S 2018 Hygiene and sanitation 6 572–5
[10] Rakhmanin Yu A and Mikhailova R I 2018 Health Risk Analysis 4 31–42
[11] Fomina S F and Stepanova N V 2018 Nutrition Issues 5 197–8
[12] Firestone M, Moya J and Choen–Hubal E 2007 Risk Anal. 27 701–14
[13] Margot T B and Foos B P 2009 Human and Ecological Risk Assessment 15(5) 923–47
[14] Peter D and Sasieniand J A 1999 American Journal of Epidemiology 9 869–75
[15] Urboecology 1990 (Moscow: Nauka) p 240
[16] P 2.1.10.1920-04 2004 Guidelines for Assessing the Risk to Public Health when Exposed to Chemicals Polluting the Environment (Moscow: Federal Center for State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia) ed Yu A Rakhmanin. et al p 129
[17] MP 2.1.4.0032-11 2011 Integrated Assessment of Drinking Water from Centralized Water Supply Systems Based on Chemical Safety Indicators (Moscow: "Federal Center for Hygiene and Epidemiology" of Rospotrebnadzor) p 37
[18] Tunakova Yu A, Novikova S V and Galimova A R 2016 Bulletin of the Samara Scientific Center of the Russian Academy of Sciences 5-3 500–4
[19] Stepanova N V and Fomina S F 2016 Innovative approach to solving the problems of our time: theory, methodology, practice (Penza: science and education) pp 7–17
[20] Tunakova Yu A, Galimova A R, Fajzullin R I and Valiev V S 2016 Research Journal of Pharmaceutical, Biological and Chemical Sciences 1 1114–7
[21] Cherp O M et al 2000 Ecological Assessment and Ecological Expertise (Moscow: Ekolayn) p 141

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