UDC 613.63/.64-092: 612.017.1]: 614.71: 546.621
DOI: 10.21668/health.risk/2021.4.05.eng

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Research article

HYGIENIC ASSESSMENT OF POPULATION HEALTH RISK UNDER EXPOSURE TO CHEMICALS THAT PENETRATE DRINKING WATER FROM HOUSEHOLD WATER MIXERS

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At present a truly vital task is to evaluate possible changes in the structure and properties of drinking water occurring in the process of delivering it to end customers.

Our research aim was to perform hygienic assessment of health risks caused by consumption of drinking water with changed chemical structure influenced by domestic faucets made from zinc alloys.

Hygienic assessment of drinking water was performed to test its conformity with the requirements fixed in the Sanitary Rules and Standards SanPiN 1.2.3685-21 "Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people". Water samples were aged in new household water mixers with their cases made from ZAM zinc alloy (a zinc alloy doped with aluminum, magnesium, and copper) at pH6 and pH9 in accordance with the State Standard GOST 34771-2021 "Sanitary-technical water mixing and distributing accessories. Testing procedures". Health risks for children and adults and population risks were assessed for situations involving oral and cutaneous introduction according to the Guide R 2.1.10.1920-04 Human Health Risk Assessment from Environmental Chemicals.

We established that water samples aged in household water mixers contained authentically elevated concentrations of metals included into ZAM alloy, namely copper, nickel, lead, and zinc, both at pH = 6 and pH = 9. We also detected enhanced organoleptic properties: color grew by 2–2.3 times and turbidity by 2.3–5 times. Carcinogenic risks caused by consuming water with changed properties turned out to be unacceptable both for children and adults. We also established that calculated hazard index for the blood system didn't conform to hygienic requirements; calculated hazard indices for the central nervous system, liver, hormonal and reproductive systems were statistically significantly higher when people consumed drinking water with changed properties. We also calculated population carcinogenic risks for the whole population in the Russian Federation based on the maximum possible exposure to drinking water with changes in its chemical properties due to household water mixers. The total population risks amounted to approximately 131 thousand cases. Our research indicates it is necessary to develop prevention activities with a carefully planned monitoring system and control over quality and use of domestic faucets.

Key words: *drinking water, domestic faucets, heavy metals, health risks.*

Providing population with qualitative drinking water is among primary tasks the state has to tackle. Priority activities in the sphere, health risk assessment included, are determined within "Ecology" National Project which is aimed at optimizing waste disposal, decreasing ambient air pollution, and raising quality of drinking water [1–4]. Drinking water quality should conform to hygienic standards at each point in water supply

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networks [4, 5]. There are multiple factors that can influence chemical structure of drinking water on its way to consumers [6, 7]. Ageing underground water supply networks are a major factor here and they create both chemical and biological health risks [8–11]. Besides, chemical structure of drinking water is influenced by equipment located directly in consumers' homes including water hoses, low quality filters and domestic faucets [6, 12]. Impacts exerted by domestic faucets on drinking water quality are primarily determined by chemical composure of an alloy a faucet is made from as well as its inactivity under exposure to natural components occurring in drinking water under different temperatures and operating conditions [9]. Aerobic and anaerobic corrosion can occur both in water supply networks and in faucets due to effects produced by iron bacteria, oxygen, and other reactive compounds in drinking water thus making for not only destruction of a faucet but also for drinking water contamination [5, 13, 14]. Simultaneously there are changes in both organoleptic and chemical properties of drinking water. When drinking water with changed chemical properties is consumed for a long time, it leads to metabolic disorders in the body, activated peroxidation, and developing environmental diseases [15–19]. At present there are multiple works available in scientific literature with their focus on mechanisms and outcomes of drinking water getting contaminated during its transportation through water supply networks but there are very few studies concentrating on changes in drinking water quality that occur due to domestic faucets. The issue becomes even more vital given the new interstate standard that has been introduced recently, namely GOST 34771-2021 "Sanitary-technical water mixing and distributing accessories. Testing procedures"[1]; the standard stipulates testing procedures for water mixing accessories that have not been applied previously to grant permissions to distribute such products on the market. Bearing this in mind, it is truly important to analyze actual exposure to compounds that come into drinking water from domestic faucets made from zinc alloys and to perform further assessment of carcinogenic and non-carcinogenic health risks [20, 21].

Our research aim was to perform hygienic assessment of health risks caused by consumption of drinking water with changed chemical structure influenced by domestic faucets made from zinc alloys.

Data and methods. Drinking water was hygienically assessed to check its conformity with the requirements fixed in the Sanitary Rules SanPiN 1.2.3685-21 "Hygienic standards and requirements to providing safety and (or) harmlessness of environmental objects for people" (issued on January 28, 2021)[2]. Water samples were tested according to the procedure stipulated in the State Standard GOST 34771-2021 "Sanitary-technical water mixing and distributing accessories. Testing procedures". This procedure is directly developed to test this type of products taking into account their construction peculiarities and operating conditions. Water samples were taken in a consumer's apartment located in Admiralteiskiy district in Saint Petersburg in accordance with the State

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[1] GOST 34771-2021. Armatura sanitarno-tekhnicheskaya vodorazbornaya. Metody ispytanii: prinyat Federal'nym agentstvom po tekhnicheskomu regulirovaniyu i metrologii 16 sentyabrya 2021 g. (vstupaet v silu s 1 iyunya 2022 g.) [GOST 34771-2021. Sanitary-technical water mixing and distributing accessories. Testing procedures: approved by the Federal Agency on Technical Regulation and Metrology on September 16, 2021 (comes into force on June 1, 2022)]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/572732675 (July 07, 2021) (in Russian).

[2] SanPiN 1.2.3685-21. Gigienicheskie normativy i trebovaniya k obespecheniyu bezopasnosti i (ili) bezvrednosti dlya cheloveka faktorov sredy obitaniya: utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha Rossiiskoi Federatsii ot 28 yanvarya 2021 goda N 2 [SanPiN 1.2.3685-21. Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people: approved by the Order by the RF Chief Sanitary Inspector on January 28, 2021 No. 2]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573500115 (July 07, 2021) (in Russian).

Standard GOST 31861-2012 "General requirements to taking water samples"[3]. Drinking water taken from centralized cold water supply network was used as a research object. Water samples (the test and the reference ones) were preliminarily prepared only to adjust pH up to 6 and 9 (the maximum and minimum permissible levels according to SanPiN 1.2.3685-21). The samples were prepared as follows. First, the test medium No. 1 or drinking water with pH = 6 was created by adding sulfuric acid solution 0.1N and controlling the result with pH-meter until pH = 6 was reached. Second, the test medium No. 2 or drinking water with pH = 9 was created by adding sodium hydrocarbonate solution 1N and controlling the result with pH-meter until pH = 8.43 was reached; after that, sodium hydroxide solution 1N was added until pH = 9.0 was reached (a detailed testing procedure is described in Item 14.3 of the GOST 34771-2021 (comes into force on June 01, 2022)). Therefore, prior to the test all the test and reference samples 1 and 2 corresponded to hygienic standards as per all the examined indicators (color, turbidity, hydrogen indicator, iron, manganese, copper, nickel, zinc, lead, aluminum, and nitrates). Both test and reference samples were prepared so that the maximum and minimum permissible pH levels were reached. Water samples with extreme pH values were aged in new domestic faucets with their cases made from ZAM zinc alloy (a zinc alloy doped with aluminum, manganese, and copper). Water from the centralized cold water supply system was kept inside the faucets for 16 or 64 hours. 16 hours were taken as a usual period of time during which a faucet was not actively used in households on working days; during this time water usually remains in a faucet case entering contacts with its inside surfaces and various admixtures can migrate from them. 64 hours were taken as a period of time during which a faucet was not used on weekends (GOST 34771-2021, comes into force on June 01, 2022). Water samples were kept under relevant temperatures during the whole test. The test was performed on a volume of water which usually fills a faucet and amounts to 250–300 ml. Overall, 90 drinking water samples were analyzed; 54 out of them were the test ones (27 samples per each extreme pH value) and 36 were the reference ones (18 samples per each extreme pH value).

Health risks were assessed for oral introduction and cutaneous exposure for children and adults in accordance with the Guide "Human Health Risk Assessment from Environmental Chemicals"[4]. Chemicals doses under oral introduction and cutaneous exposure were calculated using recommended reference values of exposure factors (Appendix 1 to the Guide R 2.1.10.1920-04). When calculating doses, we used simple mean values of maximum chemical concentrations obtained after water samples ageing in faucets for 16 hours (50 % samples) and 64 hours (50 % samples). Comparative hygienic assessment of population carcinogenic risks was performed as per maximum exposure to the analyzed chemicals in drinking water for people living in Orenburg, Saint Petersburg, Moscow, and the Russian Federation. We determined the upper limit of possible population carcinogenic risk

[3] GOST 31861-2012. Mezhgosudarstvennyi standart. Voda. Obshchie trebovaniya k otboru prob vody: prinyat Mezhgosudarstvennym sovetom po standartizatsii, metrologii i sertifikatsii (protokol ot 15 noyabrya 2012 g. N 42), vveden v deistvie s 1 yanvarya 2014 g. [GOST 31861-2012. Interstate standard. Water. General requirements to taking water samples: approved by the Interstate Council on standardization, metrology and certification (the meeting report dated November 15, 2012 No. 42), came into force on January 1, 2014]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200097520 (July 07, 2021) (in Russian).

[4] P 2.1.10.1920-04. Rukovodstvo po otsenke riska dlya zdorov'ya naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh sredu obitaniya: utv. i vvedeno v deistvie Pervym zamestitelem Ministra zdravookhraneniya Rossiiskoi Federatsii, Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii G.G. Onishchenko 5 marta 2004 g. [R 2.1.10.1920-04. Human Health Risk Assessment from Environmental Chemicals: approved and enacted by G.G. Onishchenko, the First Deputy to the RF Public Healthcare Minister and the RF Chief Sanitary Inspector on March 5, 2004]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200037399 (July 10, 2021) (in Russian).

that was calculated as a sum of population risks caused by all carcinogens in water.

All data were statistically analyzed using Statistica 10.0. Analyzed quantitative attributes corresponded to normal distribution ("chi-square" test), therefore, all obtained quantitative attributes were described with mean value (*M*) and standard error of the mean (*m*). Statistical significance of differences between independent groups was evaluated with Student's parametric t-test.

Differences were considered statistically significant at $p \leq 0.05$ and were calculated with Fisher's exact test.

Results and discussion. Hygienic assessment of drinking water quality revealed an authentic 2–2.3 times increase in color and 2.3–5.0 times increase in turbidity in the test samples. Changes in organoleptic properties, notably turbidity, were due to elevated concentrations of metals in the samples (Table 1).

We established that analyzed water samples aged in domestic faucets contained authentically higher concentrations of metals included in ZAM alloy, namely copper, nickel, lead, and zinc, both at pH = 6 and pH = 9. Copper concentration was by 30 times authentically higher in both test samples (pH = 6 and pH = 9). The test samples also contained lead in concentrations exceeding MPC and they were by 6.7 times higher than in the reference samples. We also established that nickel contents grew by almost 6 times at pH = 9 thus violating the hygienic standards; but they grew only by 2 times at pH = 6 and remained within permissible levels. Zinc was established to contaminate drinking water more intensely at lower pH values (pH = 6) against higher ones (pH = 9); its concentration exceeded MPC in the former case.

Overall drinking water contamination grew by 3.0–3.5 times at both pH values. We should note that hydrogen indicator grew in the test samples and this was due to oxidation and lower oxygen concentration.

Heavy metals penetrate drinking water in high quantities due to effects produced by domestic faucets; these metals belong to the first hazard category (lead and nickel) and their occurrence results in changes in chemical structure of drinking water. According to data obtained in multiple studies, elevated lead concentrations in drinking water induce metabolic disorders which, in their turn, cause various diseases of the endocrine, immune, and nervous systems. Besides, lead is able to accumulate in organs and tissues as well as penetrate through the placental and blood-brain barriers [17, 19]. Lead produces negative effects on the reproductive system violating spermatogenesis in men and facilitating hormonal disorders in women that are usually accompanied with more frequent miscarriages and congenital malformations. We should note that lead and nickel influence hemopoiesis by activating peroxidation that results in damage to cellular membranes; they can also act as a strumogenic factor.

Table 1

Chemicals concentrations in drinking water ($M \pm m$, compared to MPC)

Parametr	Test	Reference 1	Test	Reference 2
	pH = 6		pH = 9	
Color	**1.91 ± 0.06***	0.88 ± 0.06	**1.53 ± 0.04***	0.98 ± 0.02
Turbidity	**2.42 ± 0.09***	0.47 ± 0.07	**1.33 ± 0.07***	0.58 ± 0.03
Hydrogen indicator	0.79 ± 0.02	0.70 ± 0.07	0.96 ± 0.07	0.87 ± 0.09
Iron	0.77 ± 0.04	0.75 ± 0.06	0.75 ± 0.01	0.60 ± 0.04
Manganese	0.24 ± 0.01	0.19 ± 0.001	0.15 ± 0.01	0.15 ± 0.01
Copper	**0.15 ± 0.02***	0.005 ± 0.001	**0.16 ± 0.01***	0.002 ± 0.0001
Nickel	**0.94 ± 0.07***	0.40 ± 0.001	**3.54 ± 0.12***	0.64 ± 0.01
Zinc	**1.78 ± 0.09***	0.01 ± 0.001	**0.51 ± 0.06***	0.004 ± 0.0001
Lead	**1.93 ± 0.03***	0.29 ± 0.01	**1.65 ± 0.11***	0.27 ± 0.03
Aluminum	0.28 ± 0.04	0.21 ± 0.01	0.38 ± 0.07	0.19 ± 0.07
Nitrates	0.01 ± 0.001	0.02 ± 0.001	0.02 ± 0.001	0.02 ± 0.004

N o t e : ***** means validity of differences $p \leq 0.05$.

Hygienic assessment of carcinogenic risk for adult population revealed unacceptable carcinogenic risks caused by consuming drinking water with its chemical properties changed due to domestic faucets. Total carcinogenic risk under oral introduction was by 4 times higher at pH = 6 and by 6 times higher at pH = 9 than for reference samples. Besides, unacceptable total carcinogenic risk (CR_{wo} = 1.13E^{-04} at pH = 6 and CR_{wo} = 1.59E^{-04} at pH = 9) for adult population under oral introduction was also associated with consuming drinking water from centralized cold water supply systems (reference samples) (Table 2).

Acceptable carcinogenic risks were established for children for consuming drinking water from centralized water supply systems whereas drinking water aged in faucets created unacceptable carcinogenic risks for them (Table 2). Therefore, there is statistic authentic evidence that carcinogenic risks caused by chemicals occurring in drinking water due to its exposure to faucets are not only unacceptable but are also significantly (by many times) higher than risks caused by consuming common drinking water form centralized water supply systems.

It is important to mention that carcinogenic risks caused by consuming drinking water with changed chemical properties are within the 3rd range both for adults and children and require urgent health-improving and preventive activities.

Our hygienic assessment of non-carcinogenic risks revealed that maximum hazard indices, both for adults and children, were determined by contents of zinc, copper, nickel and lead in water samples. An important fact is that hazard indices calculated for all samples at different pH values are significantly higher for children than for adults; it is primarily due to greater exposure to chemicals relative to an average body mass (Table 3).

Table 2

Individual (*CR*) and total carcinogenic risks (CR_{wo}) caused by drinking water consumption

Population	pH	Sample	Nickel	Lead	CR_{wo}
Adults	pH6	test	**1.94E^{-04}***	**1.98E^{-04}***	**3.93E^{-04}***
		reference 1	8.28E^{-05}	3.00E^{-05}	1.13E^{-04}
	pH9	test	**7.28E^{-04}***	**1.69E^{-04}***	**8.97E^{-04}***
		reference 2	1.31E^{-04}	2.78E^{-05}	1.59E^{-04}
Children	pH6	test	**9.06E^{-05}***	**9.26E^{-05}***	**1.83E^{-04}***
		reference 1	3.86E^{-05}	1.40E^{-05}	5.26E^{-05}
	pH9	test	**3.40E^{-04}***	7.90E^{-05}	**4.19E^{-04}***
		reference 2	6.13E^{-05}	1.30E^{-05}	7.42E^{-05}

N o t e : * means differences are valid at $p \leq 0.05$.

Table 3

Hazard indices (*HI*) for chemicals in drinking water

Chemical	Adults				Children			
	pH = 6		pH = 9		pH = 6		pH = 9	
	test	reference 1	test	reference 2	test	reference 1	test	reference 2
Iron	0.022	0.021	0.021	0.017	0.05	0.05	0.05	0.04
Manganese	0.005	0.004	0.002	0.003	0.01	0.01	0.01	0.01
Copper	0.228*	0.007	0.240*	0.003	0.53*	0.02	0.56*	0.01
Nickel	0.027	0.012	0.101*	0.018	0.06	0.03	0.24*	0.04
Zinc	0.847*	0.004	0.243*	0.002	1.98*	0.01	0.57*	0.00
Lead	0.157*	0.024	0.134*	0.022	0.37*	0.06	0.31*	0.05
Aluminum	0.002	0.001	0.002	0.001	0.00	0.00	0.01	0.00

N o t e : * means differences are valid at $p \leq 0.05$.

Table 4

Hazard indices (*HI*) for critical organs and systems affected by the analyzed chemicals

Organs / systems	Adults				Children			
	pH = 6		pH = 9		pH = 6		pH = 9	
	test	reference 1	test	reference 2	test	reference 1	test	reference 2
GI tract	0.25	0.02	**0.34***	0.02	**0.59***	0.04	**0.80***	0.05
CNS	**0.16***	0.03	0.14	0.03	**0.38***	0.07	**0.32***	0.06
Blood	**1.07***	0.08	**0.52***	0.08	**2.50***	0.18	**1.21***	0.19
CVS	0.04	0.03	0.12	0.04	0.09	0.06	0.27	0.09
Immune system	0.02	0.02	0.02	0.02	0.05	0.05	0.05	0.04
Liver	**0.25***	0.02	**0.34***	0.02	**0.59***	0.04	**0.80***	0.05
Mucosa	0.02	0.02	0.02	0.02	0.05	0.05	0.05	0.04
Hormonal system	**0.16***	0.02	**0.13***	0.02	**0.37***	0.06	**0.31***	0.05
Reproductive system	**0.16***	0.02	**0.13***	0.02	**0.37***	0.06	**0.31***	0.05

N o t e : * means differences are valid at $p \leq 0.05$.

Table 5

Health risks under cutaneous exposure to chemicals in drinking water with changed chemical properties

Sample	pH	Children		Adults	
		HI	CR_{wd}	*HI*	CR_{wd}
Test	pH6	$5.45E^{-09}$	$2.32E^{-12}$	$3.32E^{-09}$	$7.07E^{-12}$
Reference 1		$1.04E^{-09}$	$6.66E^{-13}$	$6.35E^{-10}$	$2.03E^{-12}$
Test	pH9	$6.95E^{-09}$	$5.3E^{-12}$	$4.24E^{-09}$	$1.61E^{-11}$
Reference 2		$1.19E^{-09}$	$9.39E^{-13}$	$7.25E^{-10}$	$2.86E^{-12}$

Table 6

Probable population carcinogenic risk caused by consuming drinking water with its chemical quantities changed due to domestic faucets (CR pop), a number of cases

Chemical	pH	Orenburg	Saint Petersburg	Moscow	Russian Federation
Nickel	pH = 6	111	1,046	2,455	28,357
	pH = 9	417	3,920	9,213	106,413
Lead	pH = 6	113	1,066	2,506	28,942
	pH = 9	97	910	2,139	24,703
An upper limit of probable population carcinogenic risk	pH = 6	225	2,116	4,973	57,445
	pH = 9	5,148	4,830	11,352	131,115

Having assessed risks of adverse effects for critical organs and systems, we established that risks for blood didn't conform to hygienic requirements when drinking water aged in faucets was consumed and this was so both for adults and children. Besides, we detected statistically significant differences in non-carcinogenic risk rates for the central nervous system, liver, hormonal and reproductive systems (Table 4).

We also performed hygienic assessment of hazard indices for chemicals in drinking water under cutaneous exposure and established that risks of adverse effects on critical organs and systems were acceptable both for adults and children. At the same time probability of carcinogenic effects due to cutaneous exposure to drinking water with changed chemical properties was within a range from $6.66E^{-13}$ to $5.3E^{-12}$ for children and from $2.03E^{-12}$ to $1.61E^{-11}$ for adults at various pH values; this meant that risks were acceptable (Table 5).

Assessment of population health risk caused by consuming drinking water with its chemical properties changed due to using domestic faucets is a most vital stage in assessing risks of possible carcinogenic effects.

This work involved comparative assessment of population carcinogenic risks caused by drinking water aged in domestic faucets made from zinc alloys for people living in Orenburg, Saint Petersburg, Moscow, and the RF as a whole.

Probable population carcinogenic risk calculated for maximum exposure amounted to 225 (at pH = 6) and 513 (at pH = 9) additional oncologic disease cases for population in Orenburg that was equal to 572.82 thousand people; 2,116 at pH = 6 and 4,829 at pH = 9 additional cases for population in Saint Petersburg that was equal to 5,384.34 thousand people. In a megacity (Moscow as an example, overall population amounts to 12,655.1 thousand people) population carcinogenic risk may vary from 4.97 thousand additional cases (at pH = 6) to 11.35 thousand (at pH = 9). Given that domestic faucets of this label are used everywhere in the Russian Federation, a number of additional oncologic disease cases may exceed 131 thousand (Table 6).

Health risk assessment always involves assessing uncertainty. In our research this uncertainty is associated with assessing exposure under just a conditional scenario of effects produced by chemicals. Besides, only 7 metals penetrating drinking water from domestic faucets were taken into account since the analyzed alloy was made from them; exposure scenarios and routes can't be considered complete either. We should also bear in mind that the tests were accomplished according to the State Standard GOST 34771-2021 "Sanitary-technical water mixing and distributing accessories. Testing procedures" that comes into force on June 01, 2022, that is, all the existing laboratories have not been certified to performed tests according to it yet. Nevertheless, comparative assessment of risks caused by drinking water with its chemical properties changed due to domestic faucets provides a quite truthful picture of occurring adverse effects for organs and systems in the body, including some probable remote consequences (malignant neoplasms).

Conclusions. The research revealed that drinking water changed due to destruction of metals used for manufacturing domestic faucets from zinc alloys. The process results in heavy metals penetrating drinking water and these metals are tropic for organs and systems in the body.

Hygienic assessment revealed that water with changed chemical properties contained nickel and lead in quantities deviating from hygienic standards; this water also didn't conform to these standards as per its organoleptic properties (color and turbidity).

Total carcinogenic risk caused by oral introduction of chemicals with drinking water was unacceptable both for children ($4.19E^{-04}$) and adults ($8.97E^{-04}$) and was by 10 times higher than risk calculated for reference samples.

Bearing in mind that rather small amount of drinking water is exposed to faucets for a long time, non-carcinogenic risks for critical organs and systems conformed to hygienic requirements both under oral introduction and cutaneous exposure, excluding the blood system (*HI* for blood = 2.5 for children, *HI* for blood = 1.07 for adults at pH = 9); the major contribution into *HI* was made by exposure to lead.

We should note that risks were calculated taking into account only 7 metals and it created the greatest uncertainty in our risk assessment.

Our research indicates it is necessary to develop preventive activities with a well-planned system for monitoring and control over quality and operation conditions for domestic faucets used in the Russian Federation.

Future prospects in further investigations in the sphere might involve examining effects produced on health of pregnant women, newborns and other vulnerable population groups by drinking water with its chemical properties changed due to used of domestic faucets made form zinc alloys. Future studies should take into account complete exposure routes and scenarios and involve assessing all chemicals that may occur in drinking water.

Funding. The research was granted financial support by the Bathroom Manufacturers and Vendors Association.

Conflict of interests. The authors declare there is no any conflict of interests.

References

1. Averin A.N., Lyahov V.P., Evtushenko S.A., Nuvahov T.A. Znachenie natsional'nogo proekta «Ekologiya» dlya ekologicheskogo blagopoluchiya rossiiskogo naseleniya [The significance of the national project "Ecology" for the ecological well-being of the Russian population]. *Nauka i obrazovanie: hozyaistvo i ekonomika; predprinimatel'stvo; pravo i upravlenie*, 2019, vol. 107, no. 4, pp. 131–134 (in Russian).

2. Zaitseva N.V., Popova A.Yu., Onishchenko G.G., May I.V. Current problems of regulatory and scientific-medical support for assurance of the sanitary and epidemiological welfare of population in the Russian Federation as the strategic government task. *Gigiena i sanitariya*, 2016, vol. 95, no. 1, pp. 5–9. DOI: 10.18821/0016-9900-2016-95-1-5-9 (in Russian).

3. Sinitsyna O.O., Zholdakova Z.I. Metodologiya regional'nogo normirovaniya vodnykh faktorov okruzhayushchei sredy [Methodology for regional regulation of water environmental factors]. *Sanitarnyi vrach*, 2011, no. 2, pp. 025–026 (in Russian).

4. Rakhmanin Yu.A., Rosenthal' O.M. Improvement of water quality control to guarantee qualifying health and hygiene requirements. *Gigiena i sanitariya*, 2019, vol. 98, no. 2, pp. 203–204. DOI: 10.18821/0016-9900-2019-98-2-203-204 (in Russian).

5. Khasanova A.A., Chetverkina K.V., Markovich N.I. Determination of priority chemicals of water from centralized supply systems for monitoring water safety. *Gigiena i sanitariya*, 2021, vol. 100, no. 5, pp. 428–435. DOI: 10.47470/0016-9900-2021-100-5-428-435 (in Russian).

6. Vozhdaeva M.Y., Kholova A.R., Vagner E.V., Trukhanova N.V., Melnitskiy I.A., Mullodzhanov T.T., Kantor E.A. Changes in the indicators of chemical safety of drinking water in Ufa during its transportation to consumers. *Gigiena i sanitariya*, 2021, vol. 100, no. 4, pp. 396–405. DOI: 10.47470/0016-9900-2021-100-4-396-405 (in Russian).

7. Klein S.V., Zaitseva N.V., May I.V., Kir'yanov D.A. Analiz struktury i prostranstvennogo raspredeleniya potentsial'nykh riskov prichineniya vreda zdorov'yu pri osushchestvlenii khozyaistvennoi deyatel'nosti v sfere «Sbor i ochistka vody» [Analysis of the structure and spatial distribution of potential risks of harm to health due to economic activities performed in the sphere of "Collection and purification of water"]. *Aktual'nye voprosy analiza riska pri obespechenii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya i zashchity prav potrebitelei: materialy VIII Vserossiiskoi nauchno-prakticheskoi konferentsii s mezhdunarodnym uchastiem*. In: A.Yu. Popova, N.V. Zaitseva eds. Perm, 2018, pp. 154–161 (in Russian).

8. Ivanov A.V., Davletova N.H., Tafeeva E.A. Analysis of modern views on the migration of polymeric substances from the packaging into the drinking water during storage and their influence on living organisms. *Gigiena i sanitariya*, 2013, vol. 92, no. 2, pp. 25–29 (in Russian).

9. Kryazheva E.A., Boev V.M., Kryazhev D.A. Gigienicheskaya otsenka pit'evoi vody, potreblyaemoi naseleniem goroda Orenburga [Hygienic assessment of drinking water consumed by population in Orenburg]. *Al'manakh molodoi nauki*, 2018, no. 3, pp. 3–8 (in Russian).

10. Kuznetsov K.S., Belkina A.A., Yadrova A.A. Otsenka kachestva pit'evoi vody, podavaemoi iz tsentralizovannykh sistem vodosnabzheniya v g. Moskva (Rossiya) [Assessment of the quality of drinking water supplied from centralized water supply systems in Moscow (Russia)]. *Mezhdunarodnyi studencheskii nauchnyi vestnik*, 2018, no. 4 (part 4), pp. 681–685 (in Russian).

11. Lapshin A.P., Ignat'eva L.P. Qualitative composition of drinking water at the purification and transportation stages. *Vodosnabzhenie i sanitarnaya tekhnika*, 2016, no. 6, pp. 31–35 (in Russian).

12. Katola V.M. The reason for heavy metals in tap and drinking water. *Vodoochistka. Vodopodgotovka. Vodosnabzhenie*, 2015, vol. 92, no. 8, pp. 4–8 (in Russian).

13. Klein S.V., Vekovshinina S.A., Sboev A.S. Priority risk factors of drinking water and the related with it economical loss. *Gigiena i sanitariya*, 2016, vol. 95, no. 1, pp. 10–14. DOI: 10.18821/0016-9900-2016-95-1-10-14 (in Russian).

14. Zholdakova Z.I., Kharchevnikova N.V., Mamonov R.A., Sinitsyna O.O. Methods for estimating the combined effect of substances. *Gigiena i sanitariya*, 2012, vol. 91, no. 2, pp. 86–89 (in Russian).

15. Buzinov R.V., Mironovskaya A.V., Unguryanu T.N. Kachestvo pit'evoi vody v Arkhangel'skoi oblasti i ee vliyanie na sostoyanie zdorov'ya naseleniya [Drinking water quality in the Arkhangelsk region and its impact on health status of the population]. *Vodoochistka. Vodopodgotovka. Vodosnabzhenie*, 2011, vol. 44, no. 8, pp. 10–12 (in Russian).

16. Kiku P.F., Kislitsyna L.V., Bogdanova V.D., Sabirova K.M. Hygienic evaluation of the quality of drinking water and risks for the health of the population of the Primorye territoty. *Gigiena i sanitariya*, 2019, vol. 98, no. 1, pp. 94–101. DOI: 10.18821/0016-9900-2019-98-1-94-101 (in Russian).

17. Zaytseva N.V., Ustinova O.Yu., Sboev A.S. Medical and preventive technologies for risk management of health problems associated with exposure to environmental factors. *Gigiena i sanitariya*, 2016, vol. 95, no. 1, pp. 17–22. DOI: 10.18821/0016-9900-2016-95-1-17-22 (in Russian).

18. Zemlyanova M.A., Fedorova N.E., Koldibekova Yu.V. Biochemical markers of adverse effects in children exposed to chlororganic compounds through drinking water. *ZNiSO*, 2011, vol. 222, no. 9, pp. 33–37 (in Russian).

19. Zyazina T.V., Vasilyeva M.V. Testing of heavy metals in drinking water and risk assessment of developing ecopathology in urban population. *Nauka i biznes: puti razvitiya*, 2014, vol. 36, no. 6, pp. 5–10 (in Russian).

20. Rodyukova O.A., Krutilin V.E., Avchinnikov A.V. Kachestvo pit'evoi vody i sostoyanie zdorov'ya naseleniya [Drinking water quality and health status of the population]. *Sanitarnyi vrach*, 2012, no. 10, pp. 045–047 (in Russian).

21. Sboev A.S., Vekovshinina S.A. To the problem of the assessment and increase of the effectiveness of control-supervisory arrangements providing Perm region population with clear drinking water. *Zdorov'e sem'i – 21 vek*, 2015, vol. 1, no. 1, pp. 116–135 (in Russian).

Boev V.M., Georgi I.V., Kryazhev D.A., Kryazheva E.A. Hygienic assessment of population health risk under exposure to chemicals that penetrate drinking water from household water mixers. Health Risk Analysis, 2021, no. 4, pp. 50–57. DOI: 10.21668/health.risk/2021.4.05.eng

Received: 20.07.2021
Accepted: 01.12.2021
Published: 30.12.2021