

UDC 614

DOI: 10.21668/health.risk/2016.3.04

HYGIENIC ASSESSMENT OF DRINKING WATER QUALITY AND HEALTH RISKS FOR KRASNOYARSK REGION POPULATION

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The article deals with hygienic assessment of water sources quality for the centralized drinking water supply for residential use in Krasnoyarsk region. The authors have detected violation of hygienic standards, as per such parameters as iron (iron content at the level of 1.8 mg/dm³ or 6MPC has been fixed); fluorine (up to 6MPC); ammonia and ammonium nitrogen (up to 2MPC), nitrates (up to 5MPC); organochlorine compounds (chloroform, carbon tetrachloride – up to 5MPC), manganese (up to 5.5MPC), aluminum (up to 2MPC). Such carcinogenic impurities, as benz(a)pyrene, cadmium, arsenic, nickel and lead were detected in water in high concentrations. It's been found that total lifetime carcinogenic health risk for the cities and districts residents in Krasnoyarsk region, due to carcinogenic chemicals ingestion with drinking water, in 22 areas is being assessed as negligible, and doesn't require an additional mitigation measures. In 23 areas carcinogenic risk ranges within 1.0e-6 – 1.0e-5, which corresponds to criteria for risk acceptance. In 9 areas (Borodino, Lesosibirsk towns, Yeniseisk, Kazachinskiy, Partisanskiy, Pirovskiy, Rybinskiy, Sayanskiy, Uyarskiy districts) the determined lifetime individual carcinogenic risk level ranges between 1.0e-5 to 2.0e-4, which is unacceptable for the population in general. The content of arsenic in drinking water makes primary contribution to the risk level (80.8 – 98.4%). There's a higher risk of developing blood, cardiovascular diseases for the residents of Krasnoturanskiy district (HI=1.2 and HI=1.17, accordingly); bone tissue diseases and odontopathy of the Sukhobuzimskiy area residents (HI=1.04). High danger indexes are due to nitrate and fluoride. Providing the Krasnoyarsk region urban and municipal districts inhabitants with safe drinking water requires a combination of different measures with developing and implementing programs to improve water supply for residential areas.

Key words: *hygienic assessment, drinking water quality, population health, health risks.*

One of the crucial tasks in maintaining sanitary and epidemiological welfare of the Russian Federation residents is to ensure supply of a good-quality drinking water, safe in epidemiological respect and harmless in terms of chemical composition (Onishchenko G.G., Popov A.Yu., Rakhmanin Yu.A., Zaitseva N.V. and others) [3,4, 6, 9,11,12]. The problem of the population health disorders, when consuming drinking water of improper quality, is a global challenge [16-19]. At the same time it is clear that health loss results in substantial damages to national economy [5]. However, states and regions have different reasons that condition poor quality of drinking water: from natural factors to engineering issues of water usage and wastewater disposal systems [1, 7, 11]. The task of population health protection in front of arranging

conditions for active business entities requires new approaches to sanitary and epidemiological surveillance currently being realized under a pilot risk-oriented supervision model in the field of population sanitary and epidemiological welfare, including water supply of appropriate quality [10].

Water quality studies of drinking water-sources and in fact of the drinking water in Krasnoyarsk region are still urgent [2.14]. The primary water supply sources in Krasnoyarsk region are pressure and non-pressure underground water-sources that provide drinking water to 66.8% of the region's population, incl. a third of them – through infiltration water intakes. 17.7% of the region inhabitants are supplied with drinking water from the surface water-sources. Among major water bodies used by inhabitants of the territory as drinking wa-

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ter supply sources are rivers Yenisei, Angara, Kan, Chulym.

Several studies show that water quality of the surface sources and groundwater in the region varies considerably. It's being stated that the ground water in terms of its composition is chloride, sulfate-carbonate, magnesium-calcium, calcium-sodium with a salt load of up to 1.9 g/dm³, total hardness of up to 11.77 mEq /dm³. The artesian waters aquifer in the eastern part of the region is adjacent to the salt rock deposits and the groundwater aquifer – to the coal-bearing terrigenous silts of the eastern flank of Kansk-Achinsk deposits. The adverse environmental factors contribute to water hydro-chemical composition with non-optimal content of micro- and macro-elements. Morozova et al. [8] indicate that water-sources quality is greatly affected by human activities. Thus, in taiga zone, where large-scale timber storing and processing takes place, the watercourses are contaminated with soluble organic substances, primarily, with phenolic compounds, i.e. products of wood-wastes decomposition. Agricultural activities contribute to appearing sources of nitrates, pesticides, and petroleum products in water. According to Skudarnov, Kurkatov and others, drinking water contains natural radionuclides which form unacceptable risks of long-term stochastic effects [14]. The above problems were the basis for the study, the aim thereof was the hygienic assessment of drinking water quality and related risks to the population health.

Data and Methods. Hygienic assessment of water-sources quality consumable by the Krasnoyarsk region inhabitants with the purpose of centralized drinking water supply for residential use and of drinking water has been carried out based upon an in-process monitoring statistics of the business entities that operate waterworks facilities and socio-hygienic monitoring systems (over 12 thousand definitions for 2011-2015). Risk calculation has been made according to the data of the regional information fund of social and hygienic monitoring. All studies were carried out by the accredited laboratories using standardized analysis. The risk assessment was done in accordance with the provisions of the Guidance P 2.1.10.1920-04 "Guidelines on assessment of population health risk under exposure to chemicals which pollute environment" [13] taking international practice recommendations into account [15]. To analyze dynamics of primary morbidity among Krasnoyarsk region population, the authors used statistic observation forms called "Information on number

of diseases registered in patients living in the area of a medical organization service" and given by Krasnoyarsk Regional Public Health Ministry containing data for 2010-2014 period. To analyze and statistically assess the given data, the authors used MS Excel software. [2].

Results and Discussion. As per research data of 2011-2015, it's been found that the surface and underground water-sources of the centralized drinking water supply for residential use in Krasnoyarsk region, show non-compliance with hygienic standards in terms of sanitary and chemical indicators: 20.8...32.1% of samples, and by microbiological indexes of safety: 2.8...7.7% of water samples. Compared to 2014, the higher water quality of the surface and ground water-sources recorded in 2015 is related to an evident decrease in the percentage of water samples inconsistent with hygienic standards as per microbiological indexes: from 4.8 to 3.2%, and, to a lesser extent, by sanitary and chemical indicators: from 20.9 to 20.8%.

In 2015, comparing to 2014, the region improved its sanitary conditions of the drinking water surface sources: a proportion of sources that do not meet sanitary and epidemiologic rules and standards decreased from 43.9 to 37.8%, respectively. However, the sanitary state of the groundwater-sources worsened: the proportion of the ground sources non-compliant with sanitary and epidemiological rules and standards increased from 47.8 to 49.2%.

The proportion of water samples that do not meet hygienic requirements in terms of sanitary-chemical indicators, and exceeding the average index of Krasnoyarsk region in 2015 (20.8%) was recorded in 22 urban and municipal districts of Krasnoyarsk region: indicators for several priority areas of Krasnoyarsk region administration are shown in the below figure.

Water quality of the surface and underground water-sources for the centralized drinking water supply, expressed as a proportion of water samples incompliant with hygienic requirements, as per microbiological indicators, showed a higher average index over Krasnoyarsk region in 2015 (3.2%) in 13 urban areas and municipal districts. Among those are cities: Krasnoyarsk, Lesosibirsk, Achinsk; districts: Berezovskiy, Boguchany, Bolshemurtinskoy, of Emelyanovsk, Yeniseisk, Ermakovskoe, Motyginskiy, Pirovskiy, Uzhurskiy; Evenki area.

At the same time in some areas in Krasnoyarsk region we observed a stable exceeding the region average indicators of biological water-sources pollution during 2011-2015, in Lesosibirsk (the 2^d, 3^d and

the 4th ranks), in Boguchany locality (the 1st, 2^d, 7th, 10th ranks), in Uzhurskiy district (the 4th, 5th, 9th, 11th rank), the Yenisei region (during 4 years the 2^d, 5th, 6th rank), Balakhta area (the 3^d, 5th, 8th ranks over 3 years), in Nazarovo area (the 2^d, 7th, 9th rank over 3 years).

The sanitary and engineering status of the above-ground water supply facilities remains unsatisfactory: 105 water supply systems lack necessary water treatment complex, 89 water-pipes have no decontamination units required as per epidemiological indications.

In Krasnoyarsk region in 2015, comparing to 2014, there is an increase in the number of drinking water supply facilities that do not meet sanitary requirements. The proportion of such water supply systems increased from 28.3 to 32.3%, as of due to the lack of equipped disinfection systems (from 6.8 to 7.2%) and water complexes (from 6.1 to 8.6%). It should be noted, the proportion of water supply facilities that do not meet sanitary requirements, unfitted with water treatment and disinfection systems in the region is significantly lower versus similar indicators over the Russian Federation (39.4% and 13.2%, accordingly).

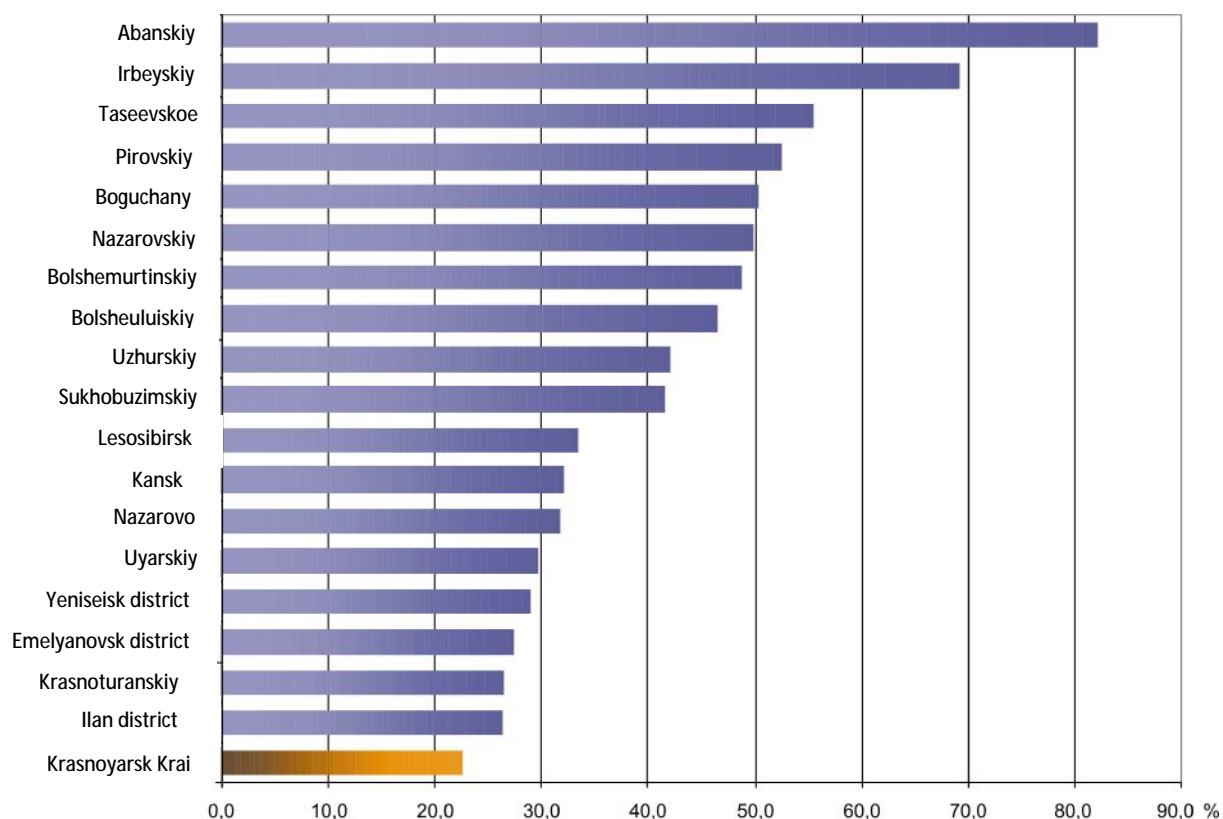


Fig.1 A proportion of samples taken from the drinking water-sources with violation of safety standards

And if the proportion of water supply systems incompliant with the sanitary and epidemiological rules and standards for the surface sources dropped significantly from 50.0% in 2014 to 38.7% in 2015, then that of the ground sources, on the contrary, increased from 27.7% to 32.2%, respectively.

Over 2011-2015 more than 50.0% of drinking water pipes did not meet sanitary standards and rules in Krasnoyarsk region' cities and districts belonging to the western localities group: Achinsk, Birilyussy, Bogotol, Bolypeuluyskiy, Tyukhtetskiy areas; the northern group: Lesosibirsk, Yeniseiskiy,

Idrinskiy, Kazachinskiy, Pirovkiy and Motyginiski areas; the Far North regions: Evenki and Taimyr (Dolgan-Nenets) areas; in Taseevskoye area of the eastern localities group and Krasnoturansk area of the southern group.

As a result, the quality of drinking water supplied to the population of certain areas in Krasnoyarsk region features a high proportion of samples that do not meet hygienic standards for chemical indicators (Dzerzhinskiy, Taseevskoye, Abanskiy, Boguchany localities, cities of Lesosibirsk and Yeniseisk, etc.) (Table 1).

According to microbiological indicators of drinking water quality from the distribution network, there are areas with 1.5-5 times exceeding the regional index of 2015 (2.7%); among them there are: Lesosibirsk, Balakhta, Berezovskiy, Birilyussy, Bolypemurtinskiy, Bolypeuluyskiy, Yenisei, Ermak, Karatuzskiy, Krasnoturansk, Novoselovskiy, Partisanskiy, Pirovskiy, Rybinsk, Sayany, Sukhobuzimskiy, Taseevskoye, Uyarskiy, Shushenskiy areas.

In 20 districts of Krasnoyarsk region, drinking water in certain years (2011-2015) shows hardness index > 10 mEq/l, the proportion of drinking water samples with hardness > 10 mEq/l varies in Krasnoyarsk region within 2.5... 4.7%, while the number of people consuming drinking water with a hardness > 10 mEq/l makes 0.3 ... 0.7% of the total region population. The authors recorded violation of hygienic standards as per such parameters as iron (cases of iron content at the level of 1.8 mg/dm^3 or 6MPC were fixed); fluorine (up to 6MPC); ammonia and ammonium nitrogen (up to 2MPC), nitrates (up to 5 MPC); organochlorine compounds (chloroform, carbon tetrachloride – to 5MPC), manganese (up to 5.5MPC), aluminum (up to 2MPC). Such carcinogens as benzo(a)pyrene, cadmium, arsenic, nickel in significant concentrations were detected in water. A violation of hygienic standards has been noted in terms of lead in Lesosibirsk, Norilsk, Yemel'yanovsk areas.

Studying chemicals data profiles revealed that consumption of drinking water incompliant with hygienic standards by the content of some chemicals, which includes compounds delivering an increased hardness (calcium and magnesium salts), represents carcinogenic risk to the population health, as well as exposure to diseases of genitourinary and endocrine systems and digestive organs.

It's been found that the total individual carcinogenic risk to the population health in Krasnoyarsk region cities and districts, due to carcinogenic chemicals ingestion with drinking water, in 22 areas does not exceed 1.0×10^{-6} being assessed as negligible, and doesn't require an additional mitigation measures

Table

Proportion of drinking water samples incompliant with hygienic standards as per chemical indicators

Administrative territory	Population, th. inhabitants	2012	2013	2014	2015	Average over 3 years
Krasnoyarsk region	2 890,3	21,6	22,2	21,9	13,5	19,8
Dzerzhinskiy area	16,73	79,5	63,8	73,3	46,9	65,9
Taseevskoe district	14,79	70,0	76,0	70,0	29,5	61,4
Abanskiy district	24,56	56,3	92,1	43,2	16,7	52,1
Boguchany district	48,90	57,1	90,9	40,8	19,1	52,0
Kozulskiy district	18,48	67,3	62,8	55,0	18,6	50,9
Tyukhtetskiy district	8,23	16,6	80,0	71,4	17,2	46,3
Kazachinskiy district	10,19	50,0	40,0	52,8	14,2	39,3
Lesosibirsk	69,90	45,9	44,7	43,1	20,8	38,6
Bolsheuluykiy district	10,14	45,7	41,6	49,5	15,2	38,0
Yeniseisk	19,18	52,6	63,3	4,9	18,9	34,9
Sukhobuzimskiy area	23,23	33,3	65,1	21,4	14,2	33,5
Krasnoturanskiy district	16,39	66,7	31,9	19,5	14,9	33,3
Turukhansk area	21,22	28,3	29,8	50,6	18,0	31,7
Irbeykiy district	17,77	22,6	45,3	41,2	17,3	31,6
Nazarovski district	24,44	36,8	39,7	32,3	16,1	31,2
Novoselovskiy area	15,84	42,5	52,2	12,5	16,2	30,9
Uzhurskiy district	34,74	32,3	31,7	31,3	21,4	29,2
Yeniseisk region	19,18	16,7	36,0	40,2	18,7	27,9
Birilyusskiy area	10,93	41,7	22,0	28,0	17,5	27,3
Pirovskiy district	8,62	63,2	29,6	3,1	10,3	26,6
Bogotolskiy district	11,85	7,7	37,5	43,8	16,9	26,5
Berezovskiy district	36,63	14,3	41,3	28,0	21,4	26,3
Achinsk region	16,51	28,8	22,6	36,3	15,9	25,9
Minusinsk region	27,55	35,6	29,7	13,8	21,2	25,1
Nizhningashkiy region	35,12	22,7	24,7	34,0	18,5	25,0
Emelyanovsk region	41,87	27,6	21,4	25,8	19,1	23,5
Sharypovski district	18,23	21,1	23,7	26,9	17,3	22,3
Rybinsk area	23,84	23,9	15,4	17,7	26,7	20,9
Uyarskiy district	22,36	1,8	10,3	28,8	39,8	20,2

In 23 areas of the Krasnoyarsk territory (cities Achinsk, Divnogorsk, Kansk, Krasnoyarsk, Nazarovo, Norilsk, Sosnovoborsk, Sharypovo,

the North-Yenisei, Motygin, Nizhneingashskiy, Emelyanovskiy, Dzerzhinskii, Ilan, Irbeyskiy Berezovskiy, Bogotol, Sukhobuzimskiy, Taimyr, Turukhanskii, Uzhurskiy, Sharypovo, Evenki districts) an individual carcinogenic risk over a lifetime-period ranges from 1.0×10^{-6} to 1.0×10^{-5} and corresponds to criteria for risk acceptance, with its upper limit for drinking water recommended by the WHO at the level of 1.0×10^{-5} which requires an ongoing monitoring.

In 9 areas (Borodino, Lesosibirsk towns, Yeniseiskiy, Kazachinskii, Partisanskiy, Pirovskiy, Rybinskiy, Sayanskiy, Uyarskiy districts) the total individual carcinogenic risk level determined within 1.0×10^{-5} to 2.0×10^{-4} is considered acceptable for occupational groups and unacceptable for the population in general. In all these areas, the primary contribution of 80.8 – 98.4% to the risk level is conditioned by the content of arsenic in drinking water being recorded in all the territories in concentrations not exceeding the maximum permissible concentration (up to 0.8MPC). In 9 areas mentioned, the total population cancer risk among the drinking water consumers ranged from 1 to 11 cases of cancer for 70 years of life expectancy, i.e. less than 1 case per year.

An assessment of potential risk to health of 54 urban and municipal districts' inhabitants in Krasnoyarsk region due to drinking water chemical pollution shows that non-carcinogenic risk factor for a particular chemical does not exceed the permissible value ($HQ = 1.0$) in all the territories of the region, except for the risk factor related to the exposure to nitrates in Krasnoturanskiy settlement (1.2) and fluorine in Sukhobuzimskiy area (1.04).

There is an increased risk of developing blood disorders, of cardiovascular system among the residents of Krasnoturanskiy district ($H1 = 1.2$ and $H1 = 1.17$ accordingly); of bone tissue diseases and odontopathy of the Sukhobuzimskiy area residents ($H1 = 1.04$). High indexes of danger are caused by nitrates containing in water in MPC exceeding concentrations, in 33.3% of water samples in Krasnoturanskiy district and fluorine in 70.8% of water samples in Sukhobuzimskiy area.

Thus, according to the data of the regional information fund of social and hygienic monitoring, the highest danger to the population health of Krasnoyarsk region from the list of the ana-

lyzed chemicals in drinking water under study, represent: arsenic in the development of carcinogenic effects; nitrates and fluoride in the development of non-carcinogenic (general toxic) effects.

Under classification of the newly diagnosed morbidity of the Krasnoyarsk region population being actually registered, the genitourinary system disorders rank third following by the class of respiratory diseases and injuries.

In 2014, in 17 areas the genitourinary system morbidity rate of the population is authentically 1.1... 2.3 times higher than the average over Krasnoyarsk region: cities Achinsk, Divnogorsk, Krasnoyarsk, Lesosibirsk, Minusinsk, Nazarovo, Norilsk, Sharypovo, districts of Achinsk, Birilyussy, Dzerzhinsk, Idrinsk, Kazachinskii, Krasnoturansk, Taseevskoye, Shushenskii, Evenki.

Urolithiasis, classified to diseases of genitourinary system, makes 4.0% of all diseases in the given class including 0.3% of children, 0.6% of adolescents, 4.5% of adults. Incident cases of urolithiasis in major proportion accrue to adult population: 98.6%.

In 2014, the urolithiasis morbidity rate of the infant population (per every 1000 children) was statistically authentically 1.1 ... 8.1 times higher than the average of Krasnoyarsk region in Achinsk, Krasnoyarsk, Nazarovo, Norilsk cities, defining them as territories "at risk".

In terms of adults urolithiasis morbidity rate, 19 areas (Lesosibirsk, Sosnovoborsk, Divnogorsk, Norilsk, Minusinsk, Nazarovo, Sharypovo cities, Novoselovskiy, Bolyneuluykiy, Dzerzhinskii, the North-Yenisei, Kazachinskii, Uzhurskiy, Krasnoturansk, Bogotol, Sukhobuzimskiy, Evenki, Turukhansk, Taimyr districts) 1.4 ... 3.6 times exceeding the region-average index refer to the territories "at risk". The incidence of adolescent urolithiasis in all the territories did not exceed the average over Krasnoyarsk region.

In 2014, comparing to 2013, there is a statistically authentic growth in the primary morbidity rate by 3.8% for blood and blood-forming organs diseases (from 3.8 to 3.9% o), for endocrine system by 4.6% (from 11.1 to 11.7% o), digestive organs by 9.6% (from 35.3 to 38.7 %o).

Analyzing the research findings of water-sources quality, water pipelines sanitary state, the centralized drinking water supply quality that

show a pronounced incompliance with the sanitary-epidemiological rules and standards, high risk to the population health, we can talk about a significant number of territories in Krasnoyarsk region, i.e. territories at risk, where relevant economic entities violate legal requirements in the field of sanitary and epidemiological welfare of the population, worsening thereby the human environment parameters (the quality of drinking water consumed) and probability of health deteriorations related thereto.

Such "territories at risk" and economic entities, being classified to the categories of high and significant risk, is a priority in a risk-oriented supervision system.

Conclusion. Providing the urban and municipal districts inhabitants of Krasnoyarsk region with safe drinking water requires a combi-

nation of different measures with developing and implementing programs to improve water supply of the residential areas.

Long-term monitoring of the water-sources quality and the centralized drinking water supply obtained under the state sanitary and epidemiological surveillance, including entities operating in Krasnoyarsk region, the estimated quantitative and qualitative characteristics of risk to population health related to water consumption, provide significant information under a risk-oriented model of supervisory activities in the field of sanitary and epidemiological welfare of the population and, depending on the degree of hazard to the population health from business entities operations, is an additional criterion for selecting the priority activities when planning.

References

1. Bezgodov I.V., Efimova N.V., Kuz'mina M.V. Kachestvo pit'evoy vody i risk dlja zdorov'ja naselenija sel'skih territorij Irkutskoj oblasti [Assessment of the quality of drinking water and risk to the population's health in rural territories in the Irkutsk region]. *Gigiena i sanitarija*, 2015, no. 2, pp. 15–19 (in Russian).
2. Vasilovskiy A.M., Kurkatov S.V., Mihajluts A.P., Skudarnov S.E. Gigiena sredy obitanija v Krasnojarskom krae [Environmental hygiene in the Krasnoyarsk region]. Novosibirsk: Nauka, 2015, pp. 61–80 (in Russian).
3. Zaitseva N.V., May I.V., Balashov S.Ju. Mediko-biologicheskie pokazateli sostojanija zdorov'ja naselenija v uslovijah kompleksnogo prirodno-tehnogenogo zagraznenija sredy obitanija [Medical and biologic parameters of the population health state in conditions of inhabitancy complex natural-technogenic pollution]. *Izvestija Samar'skogo nauchnogo centra Rossijskoj akademii nauk*, 2009, vol. 11, no. 1–6, pp. 1144–1148 (in Russian).
4. Morozova O.G., Vcherashnij P.M., Pen R.Z., Shahmatov S.A. Kachestvo pit'evoy vody v Jugo-Vostochnoj zone Krasnojarskogo kraja [The quality of drinking water in the south-east zone of the krasnoyarsk region]. *Vestnik Krasnojarskogo gosudarstvennogo agrarnogo universiteta*, 2015, no. 9, pp. 71–74 (in Russian).
5. Kleyn S.V., Vekovshinina S.A., Sboev A.S. Prioritetnye faktory riska pit'evoy vody i svjazannyj s jetim jekonomicheskij usherb [Priority risk factors of drinking water and the related with it economical loss]. *Gigiena i sanitarija*, 2016, no. 1 (95), pp. 10–14 (in Russian).
6. Kolotygina L.L. Vlijanie himicheskikh veshhestv, postupajushhih s pit'evoy vodoj, na zdorov'e naselenija [The impact of the chemical substances administered with drinking water, on population health]. *Nacional'nye priority Rossii*, 2013, no. 2 (9), pp. 48–49. Available at: <http://elibrary.ru/contents.asp?issueid=1170646> (28.08.2016) (in Russian).
7. May I.V., Kleyn S.V., Sedusova Je.V. K voprosu o porjadke provedenija sanitarno-jepidemiologicheskogo rassledovanija narushenij prav grazhdan na bezopasnoe pit'evoe vodosnabzhenie [To the question of the procedure of sanitary and epidemiological investigation of the infringement of citizens' rights for safe drinking water supply]. *Zdorov'e sem'i - 21 vek*, 2012, no. 4, pp. 11 (in Russian).
8. Onishchenko G.G. Aktual'nye zadachi gigenicheskoj nauki i praktiki v sohranenii zdorov'ja naselenija [Actual problems of hygiene science and practice in the preservation of Public health]. *Gigiena i sanitarija*, 2015, vol. 94, no. 3, pp. 5–9 (in Russian).
9. Onishchenko G.G., Zaitseva N.V. Analiz riska zdorov'ju v strategii gosudarstvennogo social'no-jekonomicheskogo razvitija: monografija [Health risk analysis of the strategy of state socio-economic development: monograph]. Moscow, Perm': Izd-vo Permskogo nacional'nogo politehnich. un-ta, 2014, 738 p. (in Russian).
10. Zaitseva N.V., May I.V., Kleyn S.V., Sedusova Je.V. Opyt ustanovlenija i dokazyvanija vreda zdorov'ju naselenija vsledstvie potreblenija pit'evoy vody, soderzhashhej produkty giperhlorirovanija [An experience of establishing and proving of harm to the public health caused by consumption of drinking water containing hyperchlorination products]. *Zdorov'e naselenija i sreda obitanija*, 2015, no. 12 (273), pp. 16–18 (in Russian).
11. Popova A.Ju. Strategicheskie priority Rossijskoj Federacii v oblasti jekologii s pozicii sohranenija zdorov'ja nacii [Strategic priorities of the Russian Federation in the field of ecology from the position of preservation of health of the nation]. *Zdorov'e naselenija i sreda obitanija*, 2014, no. 2 (251), pp. 4–7 (in Russian).

12. Rahmanin Ju.A., Mihajlova R.I. Okruzhajushhaja sreda i zdorov'e: priorityety profilakticheskoy mediciny [Environment and Health: Priorities for Preventive Medicine]. *Gigiena i sanitarija*, 2014, vol. 93, no. 5, pp. 5–10 (in Russian).

13. Rukovodstvo po ocenke riska dlja zdorov'ja naselenija pri vozdejstvii himicheskikh veshhestv, zagryaznjajushhih okruzhajushhuju sredu R 2.1.10.1920-04 [Guide to health risk assessment when exposed to chemicals polluting the environment 2.1.10.1920-04 P]. Moscow: Federal'nyj centr Gossanjepidnadzora Minzdrava Rossii, 2004, 143 p. (in Russian).

14. Skudarnov S.E., Kurkatov S.V. Riski dlja zdorov'ja naselenija v svjazi s potrebleniem pit'evoy vody centralizovannogo hozjajstvenno-pit'evogo vodosnabzhenija v Krasnojarskom krae [Health risks in connection with the consumption of drinking water of centralized drinking water supply in the Krasnoyarsk region]. *Sibirskoe medicinskoe obozrenija*, 2010, vol. 65, no. 5, pp. 50–54 (in Russian).

15. Yang Ch.Y., Chiu H.F., Chang Ch.Ch., Wu T.N., Sung F.Ch. Association of very low birth weight with calcium levels in drinking water. *Environ. Research, Section*, 2002, vol. A89, pp.189–194.

16. Birley M.H. Guidelines for forecasting the vector-borne disease implications of water resources development. Geneva: WHO, 1991, 128 p.

17. Craun GF. Waterborne disease outbreaks in the United States of America: causes and prevention. *World Health Statistics Quarterly*, 1992, vol. 45, pp. 192–199.

18. Sauvant M.P., Pepin D. Geographic variation of the mortality from cardiovascular disease and drinking water in Frenchsmallarea (PuydeDome). *Environ. Res. Sect*, 2000, vol. 184, pp. 219–227.

19. Sauvant M-P., Pepin D. Drinking water and cardio vascular disease. *FoodChem. Toxicol*, 2002, vol. 40, pp. 1311–1325.