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Research article

HYGIENIC AND HEALTH RISK ASSESSMENT OF WATER SUPPLY SYSTEMS IN ZONES INFLUENCED BY LARGE AGRICULTURAL PRODUCTIONS

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The research objects in this study are represented by some areas in Bashkortostan, which adjoin zones influenced by large agricultural productions; water from water sources used by people for drinking, household, cultural and recreational needs; sanitary-epidemiological indicators of water quality that describe pollution of water sources; levels of health risks associated with drinking water quality.

The aim of this study is to perform hygienic assessment, health risk assessment included, of water supply systems in zones influenced by large agricultural productions as a basis for substantiating relevant measures aimed at providing hygienic safety for the population (exemplified by Bashkortostan).

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We have performed sanitary-hygienic assessment of water resources located in close proximity to agricultural productions including water in surface water objects, underground water sources of non-centralized water supply (wells and springs) and centralized water supply systems. Existing sanitary-hygienic problems were found and described; substantiation was provided for the necessity to organize and implement activities aimed at preventing and mitigating health risks for population. We established main sources and reasons for occurrence of adverse chemicals and pathogens in water objects in areas where animal husbandry, poultry and vegetable-growing farms are located; substantiated a list of priority indicators recommended for control of water quality in various water sources; determined relevant safety criteria that describe adverse impacts exerted by polluted water on human health.

We have established that water quality deviating from safe standards creates elevated health risks in the analyzed areas and can make for growing incidence of non-communicable and communicable diseases among population. Hygienic recommendations and targeted measures have been developed based on our findings; they are aimed at reducing the existing technogenic burden on water objects in areas with developed agricultural industry. The obtained data are recommended to be used by institutions, bodies and organizations responsible for the state sanitary-epidemiological and environmental surveillance over water quality in water objects located in areas influenced by agricultural productions.

Keywords: *underground and surface waters, water form centralized drinking water supply systems, water use, pollution of water sources, sanitary-hygienic assessment, health risk, agricultural territories.*

Special attention is now being paid to finding solutions to sanitary and hygienic issues against growing anthropogenic effects on the environment and an associated increase in risks for humans' life and health. The main goal here is to improve quality of the environment, which is achieved by using such instruments as recovering hydrochemical properties of water systems, reducing the proportion of contaminated sewage water drained in rivers, and improving quality of drinking water supplied to the population[1]. Water quality in underground and surface sources of drinking water supply holds a significant place in promoting health protection, reducing mortality and increasing life expectancy at birth [1–3].

Activities performed by agricultural enterprises have substantial impacts on quality and composition of water in surface and underground water sources used by people for drinking, household and recreational needs. Drainage water from agricultural enterprises, which penetrates natural water systems, tends to contain elevated levels of dissolved organic compounds, pesticides, chlorides, sulfates, nitrogen compounds, and microelements including toxic heavy metals. Several studies have reported considerable levels of pollution in surface and underground water sources located in areas affected by such enterprises [4–9].

Large-scale use of pesticides is a considerable contamination factor. Volumes, in which pesticides are manufactured and used, grow annually. According to the Russian Union of Crop Protection Chemicals Manufacturers and Ministry of Agriculture of the Russian Federation, the share of Russian crop protection chemicals on the market grew from 45 % in 2016 to 70 % in 2022[2]. As highly biologically active substances, pesticides are able to circulate in the environment (water and soil), which often causes poor organoleptic properties of water (smell, color, foaming, and turbidity), leads to contamination of heavy metals salts in surface and underground waters, promotes bacterial contamination in water objects by stimulating growth of microorganisms, as well as weakens self-purification processes in water areas [10–14].

Active use of nitrogen fertilizers in crop cultivation is the largest source of man-made nitrogen pollution in surface and underground

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[1] O Strategii nauchno-tekhnologicheskogo razvitiya Rossiiskoi Federatsii: Ukaz Prezidenta Rossiiskoi Federatsii ot 28 fevralya 2024 goda № 145 [On the Strategy for Scientific and Technological Development of the Russian Federation: the RF President Order dated February 28, 2024 No. 145]. *Prezident Rossii*. Available at: http://www.kremlin.ru/acts/bank/50358 (September 11, 2024) (in Russian).

[2] Za pyat' let dolya rossiiskikh sredstv zashchity rastenii uvelichilas' s 45 % do 70 % [Over five years, the share of Russian crop protection chemicals grew from 45 % to 70 %]. *Ministry of Agriculture of the Russian Federation*, April 06, 2022. Available at: https://mcx.gov.ru/press-service/news/za-pyat-let-dolya-rossiyskikh-sredstv-zashchity-rasteniy-uvelichilas-s-45-do-70/ (September 15, 2024) (in Russian); Za pyat' let dolya rossiiskikh sredstv zashchity rastenii uvelichilas' s 45 % do 70 % [Over five years, the share of Russian crop protection chemicals grew from 45 % to 70 %]. *Delovoi kvadrat*, April 07, 2022. Available at: https://www.d-kvadrat.ru/novosti/20052 (September 15, 2024) (in Russian).

waters across the globe. Excessive use of nitrogen-based fertilizers (synthetic and / or natural) has a specifically harmful effect since the greatest part of nitrogen, which is not absorbed by plants, transforms into nitrates; the latter are easily washed off from soils into watercourses and underground waters [15, 16].

People who live in rural areas are exposed to the highest health risks since they commonly use non-centralized water sources (surface water objects, springs and wells) for drinking and household needs. As opposed to centralized water supply, such sources are not well protected from both natural and human impacts. Sanitary-epidemiological safety and proper laboratory control of water quality is not provided for a major part of such sources. Thus, safety of their use as regards epidemiological and radiation aspects or harmlessness of their chemical compositions cannot be guaranteed.

All foregoing issues related to safe water use are relevant for the Republic of Bashkortostan (RB), a leading agricultural region in the Russian Federation. The Republic owns 3.4 % (7.069 million hectares; of them, plowed fields accounting for 3636.7 thousand hectares) of all agricultural lands in Russia and produces 3.2 % of the total agricultural production in the country [17]. The agricultural sector is developing quite actively in Bashkortostan and operates practically in the whole range of agricultural brunches including animal husbandry (cattle, pig, sheep, horse, and poultry breeding) and plant cultivation (grains, legumes, oil and sugar-bearing cultures, potatoes and other vegetables). This creates elevated human impacts on water sources located in the basins of the Volga, Kama, Belaya and Ural rivers.

The aim of this study is to perform hygienic assessment, health risk assessment included, of water supply systems in zones influenced by large agricultural productions as a basis for substantiating relevant measures aimed at providing hygienic safety for the population (exemplified by Bashkortostan).

Materials and methods. The research was accomplished in some residential areas adjoining large agricultural enterprises operating in various brunches: in Sterlitamakskii district (animal husbandry, poultry breeding, and plant growing on the open ground); Ufimskii district (poultry breeding, protected cultivation and plant growing on the open ground); Alsheevskii, Buraevskii, Davlekanovskii, Karmaskalinskii, Tuimazinskii, Chekmagushevskii and Chishminskii districts (plant growing on the open ground).

The research objects in this study with its focus on assessing sanitary-hygienic state of water objects used by people for drinking, household, cultural and recreational needs are represented by some sections of water ways located close to large agricultural productions (Table 1). Selected observation points were located higher and lower along the stream than sewage disposals from agricultural objects. Samples were taken in various seasons in conformity with the State Standard GOST[3].

Population exposure was estimated using data provided by the testing center of the Ufa Research Institute of Occupational Hygiene and Human Ecology (over 2021–2023) and Bashkir Agency on Hydrometeorology and Environmental Monitoring (over 2007–2020). Quality of water from wells and springs in rural settlements was estimated per 21 indicators. The total research volume included more than 13,000 research units.

Samples were taken and analyzed to establish sanitary and hygienic characteristics of underground waters used by population as non-centralized drinking water supply sources (Table 2).

Underground water contamination was estimated per 32 priority indicators. The total research volume covered approximately 11,200 units. In addition, the analysis included the results of laboratory tests obtained by the Center for Hygiene and Epidemiology in Bashkortostan within conducting social and hygienic monitoring (SHM).

[3] GOST R 59024-2020. Water. General requirements for sampling (published with alterations No.1), approved and enacted by the Order of the Federal Agency on Technical Regulation and Metrology dated September 10, 2020 No. 640-st. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200175475 (September 07, 2024) (in Russian).

Table 1

Observation points for monitoring of surface water quality

No.	Water object	Observation points
1	Kalmashka River	Chishminskii district, close to agricultural lands
2	Lebyazh'e Lake	Ufimskii district, close to fields
3	Sosnovoe Lake	Ufimskii district, close to greenhouses
4	Soldatskoe Lake	Ufimskii district, on agricultural lands
5	Avdonskii Pond	Ufimskii district, close to a poultry farm
6	Asava River	Sterlitamakskii district, close to a pig farm
7	Kuganak River	Sterlitamakskii district, close to a pig farm
8	Yamansaz River	Sterlitamakskii district, at the boundary of agricultural fields
9	Belaya River	Sterlitamakskii district, close to agricultural lands
10	Mesel'ka River	Sterlitamakskii district, close to agricultural lands
11	Dema River	Al'sheevskii district, close to fields
12	Aslykul' Lake	Davlekanovskii district, close to land spots (plowed fields)
13	Miyaki River	Miyakinskii district, close to agricultural lands
14	Chermasan River	Chekmagushevskii district, close to fields

Table 2

Observation points for monitoring of water quality in underground sources in rural settlements in Bashkortostan

No.	Settlement	Water source
1	Ufimskii district, Avdon settlement, 3 km away from a poultry farm	Shaft well
2	Ufimskii district, Avdon settlement, 2 km away from a poultry farm	Shaft well
3	Ufimskii district, land spots for berry, fruit and vegetable growing	Well
4	Ufimskii district, cottage settlement Tsvety Bashkirii	Well
5	Ufimskii district, Alekseevka settlement, close to greenhouses	Well
6	Ufimskii district, Bachurino settlement, close to plowed fields	Well
7	Ufimskii district, Zubovo settlement, close to plowed fields	Well
8	Chishminskii district, Chishmy settlement, close to an agricultural enterprise	Well
9	Chishminskii district, Chishmy settlement, close to plowed fields	Well
10	Chishminskii district, Chishmy settlement, close to a fruit garden	Well
11	Chishminskii district, Novoabdullino village, close to plowed fields	Shaft well
12	Chishminskii district, Sanzharovka village, close to plowed fields	Well
13	Karmaskalinskii district, Novomusino village, close to a community farm	Well
14	Ilishevskii district, Verkhnemancharovo settlement, close to a grape-growing farm	Private well
15	Buraevskii district, Buraevo settlement, close to a poultry farm	Well
16	Tuimazinskii district, close to greenhouses	Well
17	Iglinskii district, Karamaly settlement, close to an animal husbandry and vegetable-growing complex	Spring
18	Sterlitamakskii district, Ishparsovo village, close to plowed fields	Community well
19	Sterlitamakskiidistrict, Roshchinskii settlement, close to Roshchinkii pig-breeding farm	Well
20	Sterlitamakskii district, Kantyukovka settlement, close to plowed fields	Well
21	Sterlitamakskii district, Naumovka settlement, close to plowed fields	Well
22	Sterlitamakskii district, Burikazgan village, close to plowed fields	Spring
23	Sterlitamakskii district, Zalivnoe settlement, close to plowed fields	Well
24	Sterlitamakskii district, Yuzhnoe village, close to plowed fields	Well
25	Sterlitamakskii district, Pervomaiskii settlement, close to plowed fields	Well
26	Sterlitamakskii district, Begenyashskoe village, close to plowed fields	Well

Quality of water taken from centralized drinking water supply systems in settlements was estimated per 51 indicators using data provided by the laboratories of the Center for Hygiene and Epidemiology in Bashkortostan, Bashkommunvodokanal (a water supplier), and Ufa Research Institute of Occupational Hygiene and Human Ecology. The total volume of analyzed water quality indicators equaled 14,600 units.

To estimate epidemiological safety of water in analyzed areas, water samples were taken and analyzed per 8 microbiological indicators: total bacterial count (22 ± 1.0 C°), total bacterial count (37 ± 1.0 C°), total (generalized) coliforms, enterococci, sulphite-reducing clostridia spores, bacteria from Escherichia coli and Pseudomonas aeruginosa species, and causative agents of intestinal infections. The total research covered 1810 research units.

Quality of water and water sources was estimated in conformity with the regulatory sanitary documents SanPiN 1.2.3685-21[4] and SanPiN 2.1.3684-21[5]. Levels of carcinogenic and non-carcinogenic health risks associated with water quality were calculated, assessed, analyzed and interpreted in conformity with the approved methodology (Guide R 2.1.10.3968-23)[6]. Exposure to chemicals in drinking water was assessed for oral intake into the body for adult people. Recommended standard physiological constants for an adult human were employed in calculating affecting doses (body mass of 70 kg, water intake of 2 liters a day, duration of exposure equal to 30 years (non-carcinogenic risk) and 70 years (carcinogenic risk)). The total volume of analyzed indicators equaled approximately 32,000 units.

Research results were statistically analyzed using Microsoft Excel and descriptive statistics methods.

Results and discussion. Agricultural lands (pastures and plowed fields), poultry-breeding and animal husbandry farms (sheds for poultry and animals, drainage water tanks, catch pits and manure storages), warehouses for keeping fertilizers and pesticides, as well as rural settlements, cottage villages and agglomerations of berry, fruit and vegetable gardens were established to be main sources of human impacts exerted on water systems in the analyzed areas in Bashkortostan.

The research results have shown iron, manganese, nickel, mercury, sulfates and oil products to be priority chemical contaminants of surface water sources (water ways and water objects) since their levels do not conform to hygienic safe standards (Table 3).

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[4] SanPiN 1.2.3685-21. Gigienicheskie normativy i trebovaniya k obespecheniyu bezopasnosti i (ili) bezvrednosti dlya cheloveka faktorov sredy obitaniya (s izmeneniyami na 30 dekabrya 2022 goda), utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha Rossiiskoi Federatsii ot 28 yanvarya 2021 goda № 2 [Sanitary Rules and Norms SanPiN 1.2.3685-21. Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people (last amended as of December, 2022), approved by the Order of the RF Chief Sanitary Inspector on January 28, 2021 No. 2]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573500115 (September 11, 2024) (in Russian).

[5] SanPiN 2.1.3684-21. Sanitarno-epidemiologicheskie trebovaniya k soderzhaniyu territorii gorodskikh i sel'skikh poselenii, k vodnym ob"ektam, pit'evoi vode i pit'evomu vodosnabzheniyu naseleniya, atmosfernomu vozdukhu, pochvam, zhilym pomeshcheniyam, ekspluatatsii proizvodstvennykh, obshchestvennykh pomeshchenii, organizatsii i provedeniyu sanitarno-protivoepidemicheskikh (profilakticheskikh) meropriyatii (s izmeneniyami na 14 fevralya 2022 goda), utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha Rossiiskoi Federatsii ot 28 yanvarya 2021 goda № 3 [Sanitary Rules and Norms SanPiN 2.1.3684-21. Sanitary-epidemiologic requirements to maintenance of territories in urban and rural settlements, to water objects, drinking water and public water supply, ambient air, soils, living spaces, exploitation of industrial and public premises, organization and c implementation of sanitary and anti-epidemic (prevention) activities (last amended as of February 14, 2022), approved by the Order of the RF Chief Sanitary Inspector on January 28, 2021 No. 3]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573536177 (September 11, 2024) (in Russian).

[6] R 2.1.10.3968-23. Rukovodstvo po otsenke riska zdorov'yu naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh sredu obitaniya [Guide R 2.1.10.3968-23 Health Risk Assessment upon Exposure to Chemical Pollutants in the Environment]. Moscow, Rospotrebnadzor, 2023 (in Russian).

Table 3

Priority indicators of water quality in surface sources located in rural areas in Bashkortostan

Sampling points	Levels, mg/l								
	Nitrates	Nitrite nitrogen	Oil products	Chlorides	Sulfates	Total iron	Nickel	Manganese	Mercury
MPL, mg/l	45	3.0	0.1	350	500	0.3	0.02	0.1	0.0005
Belaya River	1.83 ± 0.10	0.02 ± 0.003	0.08 ± 0.006	279.6 ± 38.3	46.9 ± 7.4	0.43 ± 0.10	0.011 ± 0.002	0.20 ± 0.03	-
Dema River	8.48 ± 0.90	0.009 ± 0.0008	0.32 ± 0.06	37.2 ± 3.6	321 ± 15.4	0.34 ± 0.08	0.014 ± 0.02	0.04 ± 0.01	-
Kalmashka River	5.7 ± 0.60	0.014 ± 0.002	-	22.0 ± 3.5	143 ± 14	0.10 ± 0.02	0.095 ± 0.027	0.090 ± 0.025	0.0001 ± 0.00004
Lebyazh'e Lake	9.4 ± 0.90	0.011 ± 0.003	-	87.9 ± 7.9	247 ± 25	0.059 ± 0.01	0.070 ± 0.019	0.010 ± 0.003	0.0006 ± 0.0001
Sosnovoe Lake	-	< 0.003	-	88.6 ± 8.0	208 ± 21	0.25 ± 0.05	0.093 ± 0.026	0.018 ± 0.005	0.0007 ± 0.0001
Soldatskoe Lake	6.1 ± 0.70	< 0.003	-	17.7 ± 2.8	205 ± 21	0.075 ± 0.02	0.095 ± 0.027	0.053 ± 0.015	0.0044 ± 0.0007
Aslykul' Lake	0.13 ± 0.02	0.004 ± 0.0009	0.13 ± 0.02	52.9 ± 9.2	779 ± 52.1	0.028 ± 0.004	0.005 ± 0.001	0.028 ± 0.007	0.0010 ± 0.0003
Avdonskii Pond	-	-	-	34.7 ± 3.8	94 ± 9	0.062 ± 0.017	0.014 ± 0.004	0.010 ± 0.003	0.0001 ± 0.00004
Asava River	-	-	-	19.1 ± 3.1	123 ± 12	0.15 ± 0.03	0.11 ± 0.02	0.12 ± 0.02	0.0005 ± 0.0001
Kuganak River, up the stream	-	-	-	33.3 ± 3.7	81 ± 8	0.078 ± 0.022	0.010 ± 0.003	0.11 ± 0.02	0.0010 ± 0.0002
Kuganak River, down the stream.	-	-	-	34.7 ± 3.8	300 ± 30	0.092 ± 0.026	0.010 ± 0.003	0.12 ± 0.02	0.0021 ± 0.0003
Yamansaz River	-	-	-	10 ± 1.9	258 ± 26	0.19 ± 0.04	0.017 ± 0.005	0.21 ± 0.04	0.0001 ± 0.00004
Mesel'ka River	-	-	-	13.5 ± 2.2	155 ± 15	0.21 ± 0.04	0.010 ± 0.003	0.15 ± 0.03	0.0006 ± 0.0001
Miyaki River	14.9 ± 2.8	0.02 ± 0.003	0.37 ± 0.07	16.5 ± 3.3	148.6 ± 17	0.46 ± 0.10	0.009 ± 0.002	-	-
Chermasan River	8.07 ± 0.80	0.015 ± 0.008	0.19 ± 0.02	32.5 ± 7.6	345.6 ± 21	0.092 ± 0.01	0.008 ± 0.001	0.182 ± 0.02	0.0014 ± 0.0003

Note: «-» means data not available.

Safe standards (MPL) for water objects used for drinking and household water supply are violated per levels of such chemicals as mercury (up to 8.8 MPL), nickel (up to 5.5 MPL), oil products (up to 3.7 MPL), manganese (up to 2.1 MPL), sulfates (up to 1.6 MPL), and iron (up to 1.5 MPL). Levels of pesticides, ammonium nitrogen, nitrates, nitrites, hydrogen sulfide, chlorides, phenols, zinc, copper, cadmium, lead, chromium, arsenic and others have been established to be within safe ranges established for open water sources.

Mercury is the most widely spread chemical contaminant in the analyzed agricultural areas as it is identified in elevated levels in open water sources. The highest levels of the toxicant have been found in water in the Kuganak River (up to 4.2 MPL), Chermasan River (up to 2.8 MPL), Mesel'ka River (up to 1.2 MPL), Soldatskoe Lake (up to 8.8 MPL), Aslykul' Lake (up to 2.0 MPL), and Sosnovoe Lake (up to 1.4 MPL). Mercury has not been found in water samples taken from the Dema River, Belaya River and Miyaki River.

Nickel has also been detected in elevated levels. Thus, nickel levels have reached 0.11 mg/l in water from the Asava River in some periods and this is 5.5 times higher than MPL; water from the Kalmashka River and Soldatskoe Lake, 0.095 mg/l (4.7 MPL); Sosnovoe Lake, 0.093 mg/l (4.6 MPL); Lebyazh'e Lake, 0.070 mg/l (3.5 MPL).

Manganese also tends to be identified in elevated levels in the analyzed water objects. The highest manganese levels have been established in the Belaya River and Yamansaz River (2.0–2.1 MPL), Chermasan River (1.80 MPL), and Mesel'ka River (1.5 MPL).

Levels of oil products have been established to not conform to safe standards in water from the Miyaki River (3.7 MPL), Dema River (3.2 MPL), Chermasan River (1.9 MPL), and Aslykul' Lake (1.3 MPL). Average long-term levels of oil products in water taken at the analyzed water intake points in the Belaya River have not exceeded MPLs. We have not been able to determine levels of oil products in water taken from other water areas.

Levels of iron have been found to not conform to safe standards in water samples taken from three water objects: the Miyaki River (up to 1.5 MPL), Belaya River (up to 1.4 MPL), and Dema River (up to 1.1 MPL).

Water from the Aslykul' Lake has been established to contain elevated levels of sulfates up to 1.6 times higher than the relevant MPL. Levels of sulfates higher than MPL have not been detected at any other observation point in other water areas.

Likely non-carcinogenic and carcinogenic health effects have been assessed for population as regards oral, inhalation and subcutaneous exposure to chemicals in water from open sources. The assessment results give evidence of insignificant health risks with their levels being either minimal or permissible (HI < 3.0; CR < 1.0E-05).

Assessment of sanitary-epidemiological safety has revealed that water in some open water sources does not conform to safe standards per several microbiological indicators. Thus, water samples taken from the Kalmashka River have been found to contain total coliforms (TCs) in levels reaching 720 CFU/100cm^3 and enterococci in levels up to 18 CFU/100cm^3; Kuganak River, TCs (up to 1140 CFU/100cm^3), enterococci (up to 11 CFU/100cm^3), Escherichia coli (up to 170 CFU/100cm^3); Lebyazh'e Lake, TCs (up to 610 CFU/100cm^3), Escherichia coli (up to 130 CFU/100cm^3), causative bacterial agents of intestinal infections; Sosnovoe Lake, TCs (up to 590 CFU/100cm^3), enterococci (up to 16 CFU/100cm^3); Soldatskoe Lake, TCs (up to 780 CFU/100cm^3).

Our research results give evidence of great human-induced effects produced on surface water flows and water objects located in agricultural areas in Bashkortostan; this is manifested through chemical and bacteriological contamination of water in them.

Heavy metals and sulfates as contaminants located in water sources in the analyzed areas may occur in them due to drainage water coming from animal husbandry and poultry-breeding complexes, manure storage facilities at farms and fields as well as due to active use of fertilizers and pesticides.

Elevated mercury levels established in water objects can also be explained by pesticides (mercury-containing fungicides and herbicides) having been used in these areas for a long time[7] [13, 18].

In addition, we cannot neglect the fact that water objects are located too close to oil extraction enterprises (Chishminskii, Davlekanovskii, Chekmagushevskii and other districts), processing and petrochemical productions (Ufimskii and Sterlitamakskii districts) in some analyzed agricultural areas in Bashkortostan. Consequently, they are likely to be additionally influenced by waste disposals containing a wide range of soluble and insoluble pollutants such as oil products, sulfates and heavy metals. According to the observation results, levels of pollution in surface water areas tend to be somewhat higher in such areas and they depend on a distance from oil productions and petrochemical plants; the most significant ones are identified within a 5 km radius.

High levels of bacterial contamination established in the analyzed water objects indicate that water is considerably contaminated with organic compounds and various nitrogen forms. Identified pathogens and potential pathogens such as Escherichia coli, causative agents of intestinal infections, and enterococci are microbiological indicators of fecal contamination.

Contamination with pathogens and potential pathogens may occur in water objects due to water drainage coming from poultry-breeding and animal husbandry complexes or high volumes of manure being washed off from plowed fields. Also, both Russian and foreign studies report that pesticides penetrating water objects promote high levels of bacterial contamination in water objects due

[7] Borisenko N.F., Kuchak Yu.A. Vliyanie rtut'organicheskikh pestitsidov na okruzhayushchuyu sredu i zdorov'e naseleniya [Effects of mercury-organic pesticides on human health and the environment]. *Gigiena i sanitariya*, 1989, no. 12, pp. 65–69 (in Russian).

to their ability to influence microbial communities by stimulating growth of some groups and inhibiting reproduction of others [11, 18–24].

Therefore, our research results allow us to conclude that water in surface water sources located in some agricultural areas in Bashkortostan does not conform to ecological-hygienic and sanitary-epidemiological requirements. This makes household and recreational water use unsafe for people living there and may promote growing incidence of both communicable and non-communicable diseases among the population.

Assessment of water quality in water sources for household and drinking water supply. Household and drinking water is supplied to people living in settlements located in the analyzed areas predominantly from non-centralized water supply sources (wells and springs). Drinking water is partially supplied by using a centralized water supply system to people living in the Ufimskii district (Avdon settlement, Alekseevka settlement and Zubovo settlement), Sterlitamakskii district (Roshchinskii settlement), Chishminskii district (Chishmy settlement), Buraevskii district (Buraevo settlement), and Iglinskii district (Iglino settlement) of Bashkortostan.

Sanitary-epidemiological examinations of water quality in underground sources (wells and springs) have been accomplished in some areas in Bashkortostan to estimate safety of water used by people in agricultural areas as non-centralized drinking water supply.

The results obtained by the complex estimation of water quality in underground sources give evidence that in most cases water from wells and springs in some agricultural areas in the republic does not conform to sanitary-hygienic or sanitary-epidemiological requirements (Table 4).

According to our findings, several major pollutants have been identified in drinking water in the analyzed areas in levels higher than the relevant safe standards including nitrates (up to 7.2 MPL), iron (up to 5.0 MPL), nickel (up to 4.6 MPL), mercury (up to 4.0 MPL), and manganese (up to 4.0 MPL). In addition, samples taken from some water sources contain elevated calcium (up to 2.4 MPL) and magnesium (up to 1.6 MPL) levels making water in them too hard (up to twofold higher than the safe level). Levels of ammonia, ammonium nitrogen, nitrites, pesticides, hydrogen sulfide, sulfates, phenols, chlorides, zinc, copper, lead, cadmium, chromium, arsenic, strontium, cobalt, silicon, and oil products in underground water sources have been established to be within the relevant safe ranges. Analysis of microbiological indicators that describe water quality has established non-conformity with safe standards for some water sources per total bacterial count (up to 1000 CFU/cm^3), occurrence of TCs, sulfate-reducing clostridia spores, E. coli, Citrobakter spp. and causative agents of intestinal infections.

Nitrates are the most common pollutant in underground water sources in the analyzed rural areas. Thus, high levels of nitrates have been found in 10 underground water sources: wells located in Buraevo settlement (up to 7.2 MPL), Novomusino village (up to 4.3 MPL), Begenyashskoe settlement (up to 3.8 MPL), Chichmy settlement close to plowed fields (up to 2.3 MPL), outskirts of Tuimazy town (up to 1.6 MPL), Sanzharovka village (up to 1.5 MPL), Novoabdullino village (up to 2.9 MPL), and Verkhnemancharovo village (up to 2.3 MPL); springs, in Karamaly settlement (up to 2.2 MPL) and Burikazgan village (up to 1.3 MPL).

The second significant hazardous factor is water contamination with heavy metals (nickel, mercury, iron, and manganese). Unsafe nickel levels have been established in a community well in Ishparsovo village (up to 4.6 MPL), a well in Chishmy settlement near a fruit garden (up to 3.3 MPL), a private well in Roshchinskii settlement (up to 3.2 MPL), wells in Alekseevskii settlement, near Tsvety Bashkirii cottage settlement (up to 2.9 MPL) and Bachurino village (up to 2.8 MPL); a shaft well in Avdon settlement (up to 2.4 MPL).

Table 4

Priority sanitary-chemical indicators for describing quality of underground waters in some agricultural areas in Bashkortostan

Sampling points	Estimated indicators, mg/l														
	NO_3-	NO_2-	Cl^-	SO_4	Fe	H_{total}	Ca	Mg	Ni	Mn	Hg	Cr	Cd	Pb	As
MPL, mg/L	**45**	**3.0**	**350**	**500**	**0.3**	**10.0**	**25-130**	**50**	**0.02**	**0.1**	**0.0005**	**0.05**	**0.001**	**0.01**	**0.01**
Ufimskii, Avdon, section 613	1.8	<0.003	10	117	0.044	7.3	122	15	0.040	<0.005	<0.0001	<0.01	<0.0001	0.0018	<0.005
Ufimskii, Avdon, section 614	4.2	<0.003	14.9	150	0.02	6.9	114	14	0.048	<0.005	0.0009	<0.01	0.0005	0.0013	<0.005
Ufimskii, Tsvety Bashkirii (well)	0.3	<0.003	53.9	28	0.029	9.5	144	28	0.058	0.02	<0.0001	<0.01	<0.0001	<0.001	<0.005
Ufimskii, Tsvety Bashkirii (well)	0.7	<0.003	76	122	0.83	10.8	152	40	0.051	0.305	0.0011	<0.01	<0.0001	<0.001	<0.005
Ufimskii, Alekseevka	-	<0.003	11.3	198	0.044	5.3	92	9	0.059	0.006	0.0020	0.015	<0.0001	0.0013	<0.005
Ufimskii, Bachurino	12.4	<0.003	9.7	123	0.086	6.5	89	24	0.056	0.007	0.0015	<0.01	0.0008	<0.001	<0.005
Ufimskii, Zubovo	3.3	<0.003	-	-	0.95	10.0	160	24	-	-	-	-	-	-	-
Chishminskii, Chishmy, farmland	103	<0.003	40	118	<0.01	9.3	127	37	<0.010	<0.010	<0.0001	<0.01	<0.0001	<0.001	-
Chishminskii, Chishmy, Shosseinaya St.	5.8	<0.003	32	360	0.082	13.0	166	58	<0.010	0.015	<0.0001	<0.01	<0.0001	<0.001	-
Chishminskii, Chishmy, plowed fields	11.8	<0.003	12.8	146	0.25	7.7	124	18	0.066	0.007	0.0003	<0.01	<0.0001	0.0043	<0.005
Chishminskii, Novoabdullino village	133	-	-	-	0.33	11.0	132	51	-	-	-	-	-	-	-
Chishminskii, Sanzharovka	66.6	<0.003	-	-	0.014	5.9	82	22	-	-	-	-	-	-	-
Karmaskskii, Novomusino	192	-	-	-	0.65	15.6	183	78	-	-	-	-	-	-	-
Ilishevskii, Verkhnemancharovo	103	<0.003	-	-	0.014	5.8	67	30	-	-	-	-	-	-	-
Buraevskii, Buraevo	323	<0.003	-	-	0.020	18.9	309	43	-	-	-	-	-	-	-
Tuimazskii	73.6	<0.003	-	-	0.010	10.0	100	61	-	-	-	-	-	-	-
Iglinskii, Karamaly	99.6	<0.003	-	-	0.014	5.9	82	22	-	-	-	-	-	-	-
Sterlitamakskii, Ishparsovo	-	-	84.4	84	0.80	16.5	188	87	0.092	0.40	0.0010	0.012	<0.0001	<0.001	<0.005
Sterlitamakskii, Roshchinskii	18.7	<0.003	73	95	0.079	13.2	165	61	0.065	0.042	0.0010	<0.010	<0.0001	<0.001	<0.005
Sterlitamakskii, Burikazgan	58.4	<0.003	24.1	23	0.27	8.0	110	49	0.0014	0.014	<0.0001	<0.010	<0.0001	<0.001	<0.005
Sterlitamakskii, Yuzhnoe	43.9	<0.003	14	300	1.5	11.0	150	69	0.013	0.100	<0.0001	<0.010	<0.0001	<0.001	<0.005
Sterlitamakskii, Pervomaiskii	22.4	<0.003	90	390	0.55	18.0	284	51	0.001	0.004	<0.0001	<0.010	<0.0001	<0.001	<0.005
Sterlitamakskii, Begenyashskoe	170.5	<0.003	95	70	0.20	17.9	277	60	0.0012	0.022	<0.0001	<0.010	<0.0001	<0.001	<0.005

Note: «-» means data not available.

Elevated mercury levels have been established in Alekseevka settlement (up to 4.0 MPL), Bachurino village (up to 3.0 MPL), Ishparsovo village, Roshchinskii settlement, Tsvety Bashkirii cottage settlement (up to 2.0 MP:), and Avdon settlement (up to 1.8 MPL).

Elevated iron levels have been found in underground water sources located in Yuzhnoe village (up to 5.0 MPL), Zubovo village (up to 3.5 MPL), Tsvety Bashkirii cottage settlement (up to 2.8 MPL), Ishparsovo village (up to 2.7 MPL), Novomusino village (up to 2.2 MPL), Pervomaiskii settlement (up to 1.8 MPL), and Novoabdullino village (up to 1.1 MPL).

Unsafe manganese levels have been identified in water from two wells located in Ishparsovo village (up to 4.0 MPL) and Tsvety Bashkirii cottage settlement (up to 3.0 MPL).

Elevated levels of alkaline-earth metal salts such as calcium and magnesium are another significant adverse property of underground water sources. They are responsible for high water hardness (more than 10.0 mg-eq/dm^3). Thus, water hardness has been found to exceed its safe level in wells located in Buraevo village (up to 1.9 times), Pervomaiskii settlement and Begenyashskoe village (up to 1.8 times), Novomusino village (up to 1.6 times), Chishmy settlement and Ishparsovo village (up to 1.6 times), Roshchinskii settlement (up to 1.3 times), Novoabdullino village, Yuzhnoe village and Tsvety Bashkirii cottage settlement (up to 1.1 times).

Sanitary-epidemiological studies of underground water quality have revealed water samples not conforming to safe standards per the following indicators: total bacterial count, Zalivnoe settlement (up to 160 CFU/cm^3), Vasil'evka village (up to 300 CFU/cm^3), Roshchinskii settlement (up to 500 CFU/cm^3); total coliforms, Avdon, Zalivnoe, Sanzharovka, Vasil'evka, Bachurino, and Burikazgan villages and settlements; presence of sulfate-reducing clostridia spores, Avdon settlement; Escherichia coli, Avdon, Naumovka, Vasil'evka, and Burikazgan villages and settlements; causative agents of intestinal infections, Avdon settlement. Water in non-centralized water supply sources located in other analyzed areas (Chishmy settlement, Kantyukovka village, Ishparsovo village, Alekseevka settlement) conforms to sanitary-epidemiological requirements. Tests aimed at identifying enterococci and Pseudomonas aeruginosa have not established non-conformity with safe standards in all analyzed water sources either.

Therefore, our findings are evidence that underground waters as sources of non-centralized drinking water supply in agricultural areas in Bashkortostan are affected by human activities and do not conform to safe standards.

Priority chemical pollutants occurring in underground waters include nitrates, nickel, mercury, iron, manganese, calcium, and magnesium; general water hardness is another harmful factor.

High levels of nitrates in underground waters are indicative of the fact that soil in these areas has been abundantly fertilized with nitrogen-based compounds including animal husbandry and poultry-breeding wastes (manure). This might be due to plants being incapable to absorb nitrogen fertilizers completely; the remains are then transformed into nitrates and are either accumulated in soil or lost as part of drainage. Use of nitrogen-based fertilizers (natural and synthetic) in high volumes combined with high water solubility of nitrates support their washing off into underground waters thereby polluting underground water sources [5, 15].

Human-induced pollution in underground water sources with toxic heavy metals just as open water sources in the analyzed areas is likely to be associated with drainage water coming from animal husbandry and poultry-breeding complexes, manure storage at farms and plowed fields as well as with active use of fertilizers and pesticides.

High levels of nickel in underground waters can be partially due to infiltration (washing off) of the metal from soils where it occurs due to decay of soil minerals, death and decay of plants as well as due to precipitations. Animal husbandry wastes and improper use of herbicides are another reason for accumulation of nickel and other metals in soils of agricultural land spots. Motor transport with its volumes growing every year may be another contributing factor.

High hardness of water in underground sources in the analyzed areas caused by calcium and magnesium ions obviously occurs due to natural geological factors involving salts being washed off from rocks.

Pathogens and potential pathogens, which occur in drinking water, give evidence of considerable contamination with feces and organic compounds. Possible reasons might include drainage water from animal husbandry complexes penetrating underground waters or infiltration of manure from soils of plowed fields; violated sanitary-epidemiological requirements to organization and operations of water intake facilities can also contribute to the matter.

Generalization of all research results allow us to conclude that water in underground sources (wells and springs) located in the analyzed agricultural areas in the republic does not conform to sanitary-hygienic and sanitary-epidemiological requirements. It is unsafe to be used as drinking water by people since it can create elevated risks of communicable and non-communicable diseases.

Exposure to elevated levels of nitrates, iron, manganese, nickel, mercury, magnesium, and calcium in drinking water creates possible health risks for people living in the analyzed agricultural areas. These risks are associated with diseases of the digestive organs, cardiovascular, nervous, immune and genitourinary systems as well as the hematopoietic system.

Microbial contamination of drinking water with bacterial pathogens poses a serious threat of intestinal infections. The highest risks of intestinal infections due to bacteriological contamination of drinking water have been established for people living in Zalivnoe, Vasil'evka, Roshchinskii, Avdon, Sanzharovka, Bachurino, Burikazgan, and Naumovka settlements and villages.

To achieve more objective assessment of hygienic safety as regards household and drinking water supply to the population in the analyzed agricultural areas, we have assessed likely non-carcinogenic and carcinogenic health risks associated with quality of water from non-centralized water supply sources.

According to the calculations, high levels of nitrates are the most significant health risk factors associated with chemicals in underground drinking water. The highest hazard indexes (HI above 3), which determine high non-carcinogenic health risks upon exposure to nitrates in drinking water, have been established for people living in Buraevo settlement (HQ = 4.77), Novomusino village (HQ = 3.44), and Begenyashskoe village (HQ = 3.03). So, people in these settlements face higher health risks associated with likely adverse health outcomes related to the hematopoietic system.

An alerting level of health risks (HI = 1.1–3.0) for the hematopoietic system, which are associated with high levels of nitrates in underground waters, has been established for some water sources in Chishmy settlement (HQ = 1.84), Burikazgan village (HQ = 1.10), Karamaly settlement (HQ = 1.78), Tuimazinskii district (HQ = 1.31), Verkhnemancharovo village (HQ = 1.84), Sanzharovka village (HQ = 1.20), and Novoabdullino village (HQ = 2.40).

Acceptable (permissible) levels of non-carcinogenic health risks have been established when estimating effects produced by toxicants on other organs and systems in the body (the genitourinary system, kidneys, nervous system, and developmental processes).

We have assessed carcinogenic health risks associated with exposure to carcinogenic pollutants (lead, cadmium and hexavalent chromium) in drinking water from non-centralized water supply sources. As a result, the greatest carcinogenic threat has been established to be posed by water sources located in Alekseevka settlement (CR = 7.7E-05) and Ishparsovo village (CR = 6.2E-05). Hexavalent chromium identified in water from these sources creates an alerting individual carcinogenic risk (more than 1 case per 1000 people).

Levels of the total carcinogenic risk associated with cadmium and lead in underground water are within permissible (acceptable) ranges. Thus, in Avdon settlement, the total carcinogenic risk is equal to 2.4E-06 (2.4 cases per 1 million people); Bachurino settlement, 3.7E-06 (3.7 cases per 1 million people). The major contribution is made by cadmium. The lowest total carcinogenic risk associated with lead in drinking water is equal to 4.4E-07 and has been established for a well located in Chishmy settlement.

Our analysis of data obtained by monitoring of water quality in centralized drinking and household water supply systems has revealed that water supplied to population in most analyzed areas, in general, conforms to sanitary-epidemiological requirements. Elevated water hardness is the only exclusion; it has been identified in some settlements: Zubovo (up to 1.2 MPL), Chishmy (up to 1.8 MPL), Buraevo (up to 1.11 MPL) and Avdon (up to 1.3 MPL).

Water smell in distribution networks is within its safe standards ranging between 0 and 2 scores. Such indicators as ‘color’ and ‘turbidity’ have also been within safe levels for the last 5 years.

Total mineralization as an indicator describes levels of chemicals (non-organic salts, organic compounds) dissolved in water. On average, its levels have been within its permissible range equaling 400–700 mg/l, the MPL being 1000 mg/l. Solid residue amounts have been reaching this maximum permissible level (976 mg/l) in some periods only in the distribution network in Avdon settlement.

Levels of nitrates (NO_{2}-) identified in the distribution network of Chishmy, Zubovo, and Iglino settlements vary between 0.006 and 0.009 mg/l, which is several hundred times as low as the MPL (3.0 mg/l). Levels of nitrates have been established to be below the limit of detection (0.003 mg/l) in other analyzed settlements (Alekseevka, Roshchinskii and Buraevo settlements).

Levels of nitrates (NO_{3}-) in drinking water identified at all sampling points have been considerably lower than the relevant safe standard (45.0 mg/l) and equaled 1.9–7.2 mg/l.

We should also note that centralized drinking water supply systems are very well protected from introduction of pesticides (hexachlorocyclohexane, 2,4-dichlorophenoxyacetic acid, DDT and simazine). Although plant growing is quite intensive in the analyzed areas (vegetable growing, grains and legumes), pesticides have not been identified in drinking water.

Levels of other hazardous carcinogens identified in water have been lower than maximum permissible ones and therefore they do not create unacceptable health risks.

Our calculations of likely carcinogenic and non-carcinogenic health risks caused by chemicals in water from centralized water supply systems give evidence of their levels being insignificant, either permissible or minimal.

Epidemiological safety of water from centralized drinking water supply systems in the analyzed settlements is confirmed by bacteriological tests aimed at estimating such indicators as total coliforms, total bacterial count, and Escherichia coli. The results give evidence that the foregoing microorganisms are absent.

According to our findings, water from centralized water supply systems, as opposed to non-centralized water sources, is more protected from harmful chemical and biological effects and, consequently, is more eligible for being used by people as drinking water.

The results obtained in this study have given grounds for developing hygienic recommendations and targeted activities aimed at reducing human impacts on water objects and improving drinking water quality in those areas in the republic where agricultural

Table 5

Substantiation of the necessity to develop hygienic measures for making management decisions aimed at providing safe household and drinking water supply in agricultural areas (exemplified by Bashkortostan)

<table>
<tr><th rowspan="4">Water use objects</th><th colspan="4">Unfavorable factors associated with water use</th></tr>
<tr><th colspan="3">Water being unsafe per sanitary-chemical indicators*</th><th rowspan="3">Water being unsafe per sanitary-microbiological indicators*</th></tr>
<tr><th colspan="2">Higher than MPL, times</th><th rowspan="2">Health risk level in conformity with the Guide R 2.1.10.3968-23</th></tr>
<tr><th>1.1–4.9 times</th><th>5 times or more</th></tr>
<tr><td>Non-centralized drinking water sources</td><td>Ni, Hg, Mn, Ca, Mg, $H_{total.}$</td><td>NO_3, Fe</td><td>High (HI > 6.0; CR > 1.0E-04)</td><td>TBC, SRCS***, E. coli, Citrobakter spp., BCAII****</td></tr>
<tr><td>Centralized drinking water sources</td><td>$H_{total.}$</td><td>No</td><td>Permissible (HI < 3.0; CR < 1.0E-05)</td><td>No</td></tr>
<tr><td>Water objects used for household and recreational needs</td><td>Mn, Fe, OP**, SO_4</td><td>Hg, Ni</td><td>Permissible (HI < 3.0; CR < 1.0E-05)</td><td>TCs, E.coli, enterococci, BCAII****</td></tr>
</table>

Note: * means per SanPiN 1.2.3685-21 Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people; **OP is for oil products; ***SRCS, sulfate-reducing clostridia spores; ****BCAII, bacterial causative agents of intestinal infections.

production is well developed. We have created a list of priority pollutants occurring in water from various water sources (Table 5).

The list has been sent to relevant bodies and organizations responsible for monitoring of water quality in water objects so that they can adjust the existing systems for monitoring and control in areas where agricultural enterprises, which are subject to mandatory control, are located.

Obviously, the system for protection of water objects in agricultural areas in Bashkortostan should contain some measures aimed at mitigating human-induced pollution, effective and control and prediction of pollution levels, relevant and effective decisions that help eliminate possible large-scale pollution, and providing safe water use. The system should include the following items:

– organizing automated monitoring of surface waters for recreational use (the Belaya River in Sterlitamakskii and Ufimskii districts, Dema River in Chishminskii district, Chermasan River in Chekmagushskii district, Kiganak River and Asava River in Sterlitamakskii district, Miyaki River in Miyakskii district, Aslykul' Lake) and optimizing laboratory control of water use safety performed by water suppliers and surveillance authorities;

– conducting regular scheduled inspections to check occurrence of groundwaters, their levels and quality in areas where sanitary-epidemiological requirements have been established to be violated (Alekseevka, Avdon, Tsvety Bashkirii, Zubovo, Bachurino settlements and villages in Ufimskii district; Roshchinskii, Ishparsovo, Burikazgan, Yuzhnoe, Begenyashskoe, Kantyukovka settlements and villages in Sterlitamakskii district; Chishmy, Novoabdullino, Sanzharovka settlement and villages in Chishminskii district, Buraevo settlement in Buraevskii district, Verkhnemancharovo settlement in Ilishevskii district, Tuimazy settlement in Tuimazinskii district);

– selecting a place to locate a water intake facility based on geological and hydrogeological data and results obtained by sanitary inspections of a neighboring area performed by authorized experts. A place where a water intake facility is to be built should be located in an unpolluted area not less than 50 meters up the ground water flow from the existing or potential pollution sources: dump wells, outdoor toilets, warehouses for storing fertilizers and pesticides, local enterprises, sewage systems, dumps, and cattle burial grounds;

– organizing sanitary protection zones around water intake facilities;

– systemic purification, washing and, if necessary, preventive disinfection of engineering communications (especially after emergencies) and / or timely replacement of water supply networks. In case emergencies or technical violations occur at water supply networks resulting in drinking water quality deterioration, water supply network owners (juridical or physical persons) should immediately take all necessary measures to eliminate them and inform Rospotrebnadzor institutions about such situations. In case chemical pollution persists in drinking water, a decision should be made to liquidate a water intake facility or non-centralized water supply source;

– orientating social-hygienic and environmental monitoring towards measuring priority indicators;

– creating a system for effective management as regards water supply in rural areas, a system of government responsibilities and actions aimed at providing safe water to rural communities including additional treatment facilities to make drinking water safer for consumers and additional funds allocated for investment projects aimed at developing water supply networks;

– creating an analytical database on the actual situation with water supply in rural areas;

– conducting a comprehensive inventory of water supply networks in rural areas involving estimation of their operating conditions and drinking water quality;

– developing local targeted programs and mandatory implementation of activities within the existing Clean Water municipal programs when developing, building, reconstructing and repairing water supply networks and sewage systems in rural settlements;

– developing and approving industrial control programs and plans of laboratory tests to check quality of drinking water supply. Juridical and physical persons who perform this industrial control should submit a report (every month or quarter), which covers laboratory research programs and is aimed at informing relevant Rospotrebnadzor institutions about cases when water quality has been established to not conform to safe standards;

– organizing a social service for maintaining and repairing water supply networks, wells and water treatment facilities in rural areas in the republic. Any facility is prohibited for operation without a contract on maintenance and repairing;

– providing field workers and workers employed at animal husbandry farms with bottled drinking water;

– providing socially significant objects (schools, preschool children facilities, hospitals etc.) with on-premise water treatment facilities;

– providing rural settlements with drinking water reserves;

– organizing a system for sanitary education for rural residents covering safety of household and drinking water supply.

The following measures are still relevant as secondary prevention: achieving greater healthcare activity of population and creating a culture of health protective behavior; making healthcare services more qualitative and available in rural areas; active involvement of rural residents in sanitary-hygienic programs aimed at preventing morbidity and mortality due to their leading causes.

Conclusion. Therefore, our study has shown that the existing water supply in rural areas cannot fully guarantee sanitary-epidemiological safety and harmlessness for people's health. Health risks are higher than their permissible levels and obviously it is necessary to develop hygienic measures aimed at making relevant management decisions on improving household and drinking water supply in rural areas.

The following ways can be used when selecting an optimal strategy for health risk mitigation:

– a considerable limitation imposed on disposal of hazardous chemicals into water areas achieved by improving and updating agricultural production technologies and equipment;

– creating and developing a system for biogeochemical barriers within agricultural landscapes and agricultural ecosystems to prevent toxicants from migrating to water supply sources;

– purifying soils by targeted growing and subsequent processing of plants (cultures) capable of accumulating heavy metals, pesticides and other hazardous chemicals;

– organizing and conducting medical and preventive activities in areas considered unsafe per sanitary and epidemiological indicators until health risks decline to their permissible levels.

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Competing interests. The authors declare no competing interests.

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