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Research article

ANALYZING HEALTH RISKS CAUSED BY CONTAMINATED DRINKING WATER (EXPERIENCE GAINED IN SAMARA REGION)

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Environmental contamination is still a pressing issue, in particular, contaminated drinking water sources and contaminated drinking water from centralized communal water supply systems, since it produces negative effects on human health.

Our research goal was to estimate probable impacts exerted on overall morbidity in Samara by quality of drinking water taken from centralized communal water supply systems as a most significant environmental factor. Our research tasks included taking and analyzing drinking water samples from centralized communal water supply systems; calculating carcinogenic and non-carcinogenic health risks caused by analyzed chemicals.

To fulfill the tasks and achieve the goals, in 2018–2019 we performed sanitary-chemical analysis of drinking water quality as per 20 sanitary-chemical parameters; our research object was drinking water taken from centralized communal water supply systems in 7 districts in Samara. Obtained actual data on contamination of water taken from centralized water supply networks in Samara were used as primary basis for calculating hazard indexes and carcinogenic risk coefficients using conventional exposure scenarios.

In our research we revealed that maximum total non-carcinogenic hazard quotient was determined by arsenic and petroleum products introduction. Assessment of carcinogenic risks caused by contaminants in drinking water revealed that total health risk for children younger than 18 was within the second range as per its median; total carcinogenic risks for adults, within the third range. At the same time, arsenic contents did not exceed hygienic standards in all examined samples.

So, we assessed carcinogenic and non-carcinogenic risks, basing on actual data on quality of drinking water taken from centralized communal water supply systems. It seems vital to perform a wider-scale controlled study in several regions in order to assess significance of revealed factors for morbidity among population.

Key words: *centralized communal water supply, carcinogenic risks, non-carcinogenic risks, sanitary-chemical analysis, ecological monitoring, petroleum products, heavy metals, drinking water.*

The environment produces variable effects on a human body. As per data obtained via epidemiologic observations, environmental contamination influences prevalence of various diseases as well as their severity [1]. Considerable share of overall disease burden is environmentally induced since practically the whole range of technogenic emissions is made up of toxicants that are able to produce acute or chronic effects on a body depending on a dose. Sub-threshold and thresholds impacts exerted by chemical factors occurring due to anthropogenic contamina-

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tion are of special concern since they may cause non-specific pathological processes [1].

Most part of population living on urban territories is to a certain extent exposed to anthropogenic factors. Ecologic and hygienic conditions existing in different republics, regions, and autonomous areas are, on the one hand, determined by specific local natural and climatic conditions and, on the other hand, by essence and scale of impacts exerted by industry, transport, agriculture, and communal activities on the environment [1, 2].

At the same time, impacts exerted by most chemicals on health when various occupational activities are performed have been studied quite profoundly; but as for scales and gravity of consequences caused by chronic exposure to anthropogenic (and natural) contaminants occurring in the environment in insignificant (trace) quantities, they are being actively examined at the moment [2].

As per data provided by the WHO European Regional Office, ambient air contamination with chemicals is a priority risk factor that causes mortality and overall morbidity; this contamination can cause untimely death due to ischemic heart disease, stroke, chronic obstructive lung disease, oncologic diseases, etc. [1]

However, world ecological priorities also include studies on sanitary-chemical conditions of water sources and drinking water which is an integral part of any proper life activity. Chemical contamination of drinking water can contribute into chronic diseases occurrence and development including neoplasms, gastrointestinal disorders, disorders of the nervous system etc. [2–5].

There were epidemiologic examinations performed with participating children who lived in settlements where chlorinated organic compounds occurred in excessive quantities in drinking water; these examinations revealed that almost in 100 % children's biological media contained chloroform and it was detected practically on each examined territory; also, 1,2-dichloroethane was detected in some settlements (12.5 % cases). Both these substances are carcinogenic.

Diseases caused by poor quality of drinking water can also occur in a body due to disturbed balance between its internal and external environment which is typical for endemic diseases. For example, it has been detected that fluorosis that occurs in many regions in the world is caused by excessive intake of fluorides with dirking water; endemic goiter develops due to insufficient iodine concentration in drinking water and food products and besides this disease can be related to effects produced by certain chemicals that disturb balance in the hormonal system [5, 6].

In the Russian Federation the Volga River is the primary water source for drinking water supply in most regions located in the European part of the country. Its total flow accounts for practically one quarter of the overall river flow in this part of Russia (260 km^3)[2]. Surface waters in Volga basin are exposed to anthropogenic burdens that differ in scale and danger. Volga basin is contaminated due to industrial and communal sewage being introduced into it. Sewage is discharged into the river in the greatest amounts in such cities as Moscow, Samara, Nizhniy Novgorod, Yaroslavl, Saratov, Ufa, Volgograd, Balakhna, Tolyatti, Ulyanovsk, Cherepovets, Naberezhnye Chelny, etc. There is no positive long-term dynamics of water contamination detected for most watercources in Volga basin that is among water objects in the Russian Federation with maximum burden and contamination varying from high (HC) to extremely high (EHC) (905 out of 2,743 HC and EHC cases registered in 2018). More than 10 cases were registered in Astrakhan, Kirov, Moscow, Nizhniy Novgorod, Ryazan, Samara, Sverdlovsk, Tver, Tula, Chelyabinsk, and Perm regions and Udmurtia[2].

Substantial contamination of surface waters in Volga basin can't fail to influence

[1] The guide on complex prevention of environmentally induced diseases basing on risk assessment. Moscow, 2017, 68 p.

[2] On the conditions and use of water sources in the Russian Federation in 2018: The State Report. Moscow, NIA-Priroda, 2019, 290 p.

drinking water supply and population health. Samara region and Samara city in particular are among RF regions that are exposed to great anthropogenic burdens; the Saratov water reservoir is the primary source for drinking water supply on these territories. In 2018 experts detected that surface waters quality in the reservoir deteriorated; there was a growth from 0 to 38 % in a number of cases of contamination with petroleum products in concentrations equal to 1–2 MPC detected in 2018 against 2008–2017; a number of cases when contamination with copper compounds was detected grew to 47 %. Besides, there were cases when water turned out to be contaminated with ammonium nitrogen, concentration being up to 2 MPC; nitrite nitrogen, 1–3 MPC; cadmium compounds, from 1 to 2 MPC[4]. Underground waters in Samara Zarechye are another source for drinking water supply in some districts in Samara city.

Our research goal was to assess probable impacts exerted on overall morbidity in Samara by quality of drinking water taken from centralized water supply systems as a most significant environmental factor.

Our research tasks included the following:

– to analyze overall morbidity in Samara region in comparison with average morbidity in the country and average data on the Privolzhskiy Federal District since Samara region is included into it;

– to take and analyze samples of drinking water from centralized communal water supply systems;

– to calculate carcinogenic and non-carcinogenic risks caused by chemicals included into the analysis;

– to assess a probable relation between increased morbidity and calculated risk values.

Data and methods. To achieve our goals and solve the tasks, in 2018–2019 we performed sanitary-chemical analysis of drinking water quality taken from centralized dirking water supply networks in 7 districts within Samara city. Samples were taken in apartments belonging to water consumers according to GOST R 56237-2014[3]. Water samples were examined as per 20 sanitary-chemical parameters (Table 1). Drinking water quality was assessed according to requirements fixed in the SER 2.1.4.1074-01[4].

Obtained actual data on drinking water contamination in Samara city districts were primary data for calculating hazard indexes and carcinogenic risk coefficients basing on standard exposure scenarios. Health risks were assessed according to the Guide R 2.1.10.1920-04[5]. An algorithm used to analyze health risks included 4 basic stages: hazard identification, analysis of "dose – response" dependence, exposure calculation, and health risk calculation. Standard exposure factors were applied in all calculations performed in the present work. Carcinogenic risk was calculated via multiplying a daily dose (I) by carcinogenic potential factor (SFo): $CR = I \cdot SFo$ (1). Hazard quotient value (HQ) was determined via dividing annual average concentration (C) by reference concentration (RfC) (2): $HQ = C/RfC$ (2). In case there were several contaminants, hazard index (*HI*) was calculated for their simultaneous introduction into a body as per the following formula: $HI = \sum HQ$.

Results were statistically processed with Statistica for Windows (Release 6.0, StatSoft Inc.) and MS Excel for Windows. We applied Kolmogorov – Smirnov test to check whether values were distributed normally in a sampling. In case a sampling deviated from normal distribution, data were presented as median and range (minimum and maximum values and 10-th and 90-th percentiles). Differences between districts with surface and underground water supply were estimated with Student's *t*-test and were considered valid in case probability degree was higher than 95 % ($p < 0.05$).

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[3] GOST R 56237-2014. Drinking water. Taking samples at water treatment facilities and from distribution systems. Moscow, Standartinform Publ., 2019, 27 p.

[4] SER 2.1.4.1074-01. Drinking water and water supply in settlements. Drinking water. Hygienic requirements to quality of water in centralized drinking water supply systems. Quality control. Hygienic requirements to providing safety of hot water supply systems. Sanitary-epidemiologic rules and standards. Moscow, The RF Public Healthcare Ministry Publ., 2002, 103 p.

[5] R 2.1.10.1920–04. The Guide on assessing population health risks caused by exposure to chemicals that pollute the environment. Moscow, The Federal Center for State Sanitary and Epidemiologic Surveillance of the RF Public Healthcare Ministry Publ., 2004, 143 p.

Table 1

Assessed sanitary-chemical parameters and regulatory documents that stipulate rules and procedures for examining and assessing water quality

No.	Examined parameter	Measuring unit	MPC	A document that stipulates rules and procedures for examinations (tests) and measurements
1	Smell	scores	Not higher than 2	GOST R 57164-2016
2	Turbidity	mg/dm³	1.5	GOST R 57164-2016
3	Color	degrees	20	GOST 31868-2012
4	pH	pH	6-9	FR 1.31.2018.30110
5	Hardness	° H	7.0	GOST 31954-2012
6	Solid residue	mg/dm³	1.000	GOST 18164-72
7	Permanganate oxidation (PO)	mg/dm³	5.0	GOST R 55684-2013
8	Petroleum products	mg/dm³	0.1	GOST R 51797-2001
9	Sulfates	mg/dm³	500	GOST 31940-2012
10	Chlorides	mg/dm³	350	GOST 4245-72
11	Ammonium and ammonium ions	mg/dm³	2.0	GOST 33045-2014
12	Nitrites	mg/dm³	3.0	GOST 33045-2014
13	Nitrates	mg/dm³	45	GOST 33045-2014
14	Cadmium	mg/dm³	0.001	PND F 14.1: 2: 4.69-96 PND F 14.1: 2: 4.149-99
15	Lead	mg/dm³	0.03	PND F 14.1: 2: 4.69-96 PND F 14.1: 2: 4.149-99
16	Zinc	mg/dm³	5.0	PND F 14.1: 2: 4.69-96 PND F 14.1: 2: 4.149-99
17	Copper	mg/dm³	1.0	PND F 14.1: 2: 4.69-96 PND F 14.1: 2: 4.149-99
18	Arsenic	mg/dm³	0.05	FR.1.31.2002.00589
19	Iron (total)	mg/dm³	0.3	GOST 4011-72
20	AASSA (Anion-active synthetic surface-active agents)	mg/dm³	0.5	GOST 31857-2012

Note: MPC means maximum permissible concentration

Results and discussion. According to results obtained via sanitary-chemical analysis, analyzed drinking water samples conformed to obligatory requirements as per many sanitary-chemical parameters[2]. There were sporadic samples of drinking water supplied from the Saratov water reservoir that deviated from hygienic standards as per such parameters as color, iron contents, permanganate oxidation; some samples of drinking water taken from underground water sources (Kyibyshevskiy district and Krasnaya Glinka settlement in Krasnoglinskiy district) deviated from hygienic standards as per water hardness and solid residue. We also detected petroleum products contents that were higher than hygienic standards (0.1 mg/dm^3) and it can indicate that water treatment was not efficient as well as that pipes in distribution networks were in poor condition. We also detected iron in contents being higher than maximum permissible concentration (MPC) in certain samples if drinking water taken in Kyibyshevskiy, Zheleznodorozhniy, and Krasnoglinskiy districts; it might be due to engineering infrastructure being worn out. All the other metals were detected in water samples in quantities that did not exceed hygienic standards.

Table 2 contains the results obtained via drinking water analysis as per several sanitary-chemical parameters.

Actual data on drinking water quality obtained in city districts in Samara were used for calculating hazard indexes and carcinogenic risk coefficients.

In 2018 total carcinogenic risks caused by drinking water varied from $1.5 \cdot 10^{-6}$ to $6.0 \cdot 10^{-4}$ (the median was $4.9 \cdot 10^{-5}$; 10-th and

Table 2

Quality of drinking water supply to population in Samara ($M \pm m$)

District		Chlorides, mg/dm^3	Sulfates, mg/dm^3	Iron, mg/dm^3	Ammonium ions, mg/dm^3	Nitrites, mg/dm^3	Nitrates, mg/dm^3	Petr. products, mg/dm^3	As*, mg/dm^3	Pb, mg/dm^3	Cd, mg/dm^3
MPC		350	500	0.3	2.0	3.0	45	0.1	0.05	0.03	0.001
1	2018	29.1 ± 2.0	76.6 ± 8.36	0.10 ± 0.02	0.32 ± 0.06	<0.003	2.05 ± 0.30	0.34 ± 0.17	0.006 ± 0.002	<0.001	<0.001
	2019	38.4 ± 2.0	63.4 ± 7.0	0.55 ± 0.13	0.10 ± 0.03	<0.003	4.95 ± 0.74	0.15 ± 0.08	0.008 ± 0.002	<0.001	<0.001
2	2018	26.3 ± 2.0	350.6 ± 38.6	0.52 ± 0.0	0.83 ± 0.17	0.11 ± 0.04	7.14 ± 1.07	0.50 ± 0.25	0.004 ± 0.001	<0.001	<0.001
	2019	20.2 ± 2.0	234.1 ± 25.8	0.49 ± 0.11	0.20 ± 0.04	0.05 ± 0.03	7.75 ± 1.16	0.76 ± 0.19	0.008 ± 0.002	<0.001	<0.001
3	2018	169.0 ± 2.0	448.0 ± 49.0	0.12 ± 0.02	0.83 ± 0.17	0.30 ± 0.08	6.04 ± 0.91	0.17 ± 0.08	0.008 ± 0.002	<0.001	<0.001
	2019	163.2 ± 14.0	98.5 ± 10.0	0.25 ± 0.06	0.36 ± 0.07	0.08 ± 0.04	6.27 ± 0.94	0.17 ± 0.08	0.008 ± 0.002	<0.001	<0.001
4	2018	26.3 ± 2.0	48.1 ± 5.3	0.13 ± 0.02	0.34 ± 0.07	<0.003	1.68 ± 0.33	0.43 ± 0.21	0.006 ± 0.001	<0.001	<0.001
	2019	20.2 ± 2.2	52.0 ± 5.7	0.28 ± 0.07	0.40 ± 0.08	<0.003	3.85 ± 0.58	0.22 ± 0.11	0.012 ± 0.002	<0.001	<0.001
5	2018	22.6 ± 2.0	53.3 ± 5.8	0.13 ± 0.03	0.39 ± 0.08	<0.003	1.62 ± 0.32	0.43 ± 0.21	0.004 ± 0.001	<0.001	<0.001
	2019	42.2 ± 4.6	61.8 ± 6.8	0.22 ± 0.05	0.34 ± 0.07	<0.003	5.00 ± 0.75	0.15 ± 0.08	0.004 ± 0.001	<0.001	<0.001
6	2018	75.2 ± 6.5	201.2 ± 22.1	2.91 ± 0.62	0.96 ± 0.19	<0.003	7.70 ± 1.15	0.21 ± 0.10	0.026 ± 0.006	0.0023 ± 0.0003	<0.001
	2019	73.0 ± 6.3	136.0 ± 15.0	0.06 ± 0.01	< 0.10	< 0.003	15.87 ± 2.40	0.20 ± 0.10	0.005 ± 0.001	0.004 ± 0.001	0.0010 ± 0.0002
7	2018	27.3 ± 2.5	43.4 ± 4.7	<0.05	0.69 ± 0.14	0.19 ± 0.07	0.18 ± 0.03	0.41 ± 0.20	0.005 ± 0.001	<0.001	<0.001
	2019	42.2 ± 4.6	83.1 ± 9.1	0.23 ± 0.06	0.19 ± 0.04	<0.003	4.97 ± 0.75	0.40 ± 0.20	0.003 ± 0.001		<0.001
8	2018	25.4 ± 2.0	46.4 ± 5.1	0.15	0.42 ± 0.08	<0.003	1.94 ± 0.38	0.57 ± 0.14	0.006 ± 0.001	<0.001	<0.001
	2019	38.4 ± 4.1	79.4 ± 8.7	0.15 ± 0.04	0.16 ± 0.03	<0.003	5.26 ± 0.79	0.24 ± 0.12	0.008 ± 0.002	<0.001	<0.001
9	2018	23.5 ± 2.0	44.9 ± 4.9	<0.05	0.30 ± 0.05	<0.003	1.79 ± 0.35	0.68 ± 0.17	0.008 ± 0.002	0.0022 ± 0.0003	<0.001
	2019	40.0 ± 4.3	58.1 ± 6.4	0.16 ± 0.04	0.19 ± 0.04	<0.003	4.57 ± 0.68	0.37 ± 0.18	0.004 ± 0.001	<0.001	<0.001
10	2018	22.6 ± 2.0	40.5 ± 4.4	0.11	0.21 ± 0.04	<0.003	1.78 ± 0.35	0.22 ± 0.11	<0.002	0.004 ± 0.003	<0.001
	2019	41.3 ± 4.5	50.0 ± 5.5	0.26 ± 0.06	0.34 ± 0.07	<0.003	4.56 ± 0.68	0.17 ± 0.08	0.0020 ± 0.0004	<0.001	<0.001
11	2018	25.4 ± 2.1	71.3 ± 7.8	0.15	0.28 ± 0.05	<0.003	2.16 ± 0.32	0.21 ± 0.10	0.006 ± 0.002	<0.001	<0.001
	2019	41.3 ± 4..5	54.1 ± 6.0	0.31 ± 0.07	0.10 ± 0.03	<0.003	4.71 ± 0.70	0.27 ± 0.13	0.021 ± 0.004	0.0012 ± 0.0001	<0.001
12	2018	94.0 ± 8.7	386.2 ± 42.5	0.19 ± 0.03	0.66 ± 0.13	0.17 ± 0.06	5.96 ± 0.89	0.16 ± 0.08	0.007 ± 0.002	<0.001	<0.001
	2019	193.9 ± 17.5	415.0 ± 45.6	0.22 ± 0.05	0.31 ± 0.06	0.011 ± 0.005	6.78 ± 1.02	0.20 ± 0.10	0.009 ± 0.002	<0.001	<0.001

Note: 1 is Zheleznodorozhniy district; 2 is Kyibishevskiy district; 3 is Kyibishevskiy district (Volgar'); 4 is Krasnoglinskiy district (Novaya Samara); 5 is Krasnoglinskiy district (Koshelev); 6 is Krasnoglinskiy district (Krasnaya Glinka settlement); 7 is Samarskiy district; 8 is Leninskiy district; 9 is Promyshlenniy district; 10 is Kirovskiy district; 11 is Sovetskiy district; 12 is Yuzhniy gorod.

90-th percentiles were $3.0 \cdot 10^{-5}$ and $6.7 \cdot 10^{-5}$ accordingly) for children who lived on the examined territories in the city and corresponded to the second range or maximum permissible risk as per median and 90-th percentile according to R 2.1.10.1920–04 (Table 2). Also, in 2018 total carcinogenic risks for adults varied from $2.0 \cdot 10^{-5}$ to $4.5 \cdot 10^{-4}$ (the median was $1.0 \cdot 10^{-4}$; 10-th and 90-th percentiles were $1.3 \cdot 10^{-5}$ and $1.4 \cdot 10^{-4}$ accordingly) and corresponded to the third range as per the median and 90-th percentile (individual lifelong risk varied from $1 \cdot 10^{-4}$ to $1 \cdot 10^{-3}$); it was acceptable for occupational groups and unacceptable for population in general.

In 2019 corresponding median values calculated for individual carcinogenic risks amounted to $1.4 \cdot 10^{-4}$ and $6.4 \cdot 10^{-5}$ for adults and children respectively and there were no statistically authentic difference in these values against those obtained for 2018 ($p > 0.05$).

It was detected that in 2018–2019 individual carcinogenic risks were caused predominantly by impacts exerted by arsenic in all the examined city districts (Table 3). In 2018 lead made a contribution into total hazard index in three examined districts (Krasnaya Glinka settlements in Krasnoglinskiy district, Promyshlenniy district, and Kirovskiy district). The median of individual risk occurring due to effects produced by this contaminant amounted to $5.9 \cdot 10^{-7}$ (negligible risk) and $1.3 \cdot 10^{-6}$ (the second range) for children younger than 18 and adults respectively. In 2019 lead was detected in samples taken in Krasnaya Glinka settlement and Sovetskiy district in concentrations that caused median individual carcinogenic risk being equal to $7.2 \cdot 10^{-7}$ for children and $1.6 \cdot 10^{-6}$ for adults older than 18. Besides, in 2019 one sample taken in Krasnaya Glinka settlement contained cadmium in a concentration that caused median carcinogenic risk being equal to $2.0 \cdot 10^{-6}$ and $4.2 \cdot 10^{-6}$ (the second range) for children and adults older than 18 respectively.

We assessed health risks related to non-carcinogenic effects among population living in Samara caused by drinking water from centralized water supply; assessment was performed as per the same chemicals.

Calculated risks of non-carcinogenic effects were higher than permissible hazard levels: in 2018 median hazard index (range) amounted to 1.032 (0.384–3.024) and 2.407 (0.895–7.055) for adults and children respectively; in 2019, 1.055 (0.464–2.323) and 2.462 (1.082–5.419) respectively.

Total non-carcinogenic risk for children was higher than permissible levels in 2018 in 11 out of 12 examined districts (the median hazard index amounted to 2.407, the range was 0.895–7.055); the highest value was detected in Krasnaya Glinka settlement (7.055). We detected hazard quotients that were higher than permissible levels for certain critical organs and systems (the central nervous system, the range was 0.293–5.476; skin, 0.236–6.054; the cardiovascular system, 0.225–5.475; the kidneys, 0.341–1.44).

The greatest contribution here was made by arsenic since it was detected in doses higher than reference ones in all districts except Kirovskiy (the median value was 1.385 (range was 1.065–5.434)) (Table 4). Hazard quotients for petroleum products were also higher than permissible risk levels in three districts: Kyibishevskiy district, 1.065; Leninskiy district, 1.215; Promyshlennniy district, 1.440. Carcinogenic risk values were also within a range from 0.8 to 1.0 in another two districts, Krasnoglinskiy district – Novaya Samara and Koshelev. Individual hazard quotients calculated for sulfates, ammonium ions, nitrites, and nitrates were authentically higher in districts with drinking water supplied from underground sources than in districts where drinking water was supplied from surface ones ($p < 0.05$) (Table 4). Non-carcinogenic risks caused by iron amounted to 0.1 for children in 2018 excluding two territories (Kyibishevskiy district and Krasnaya Glinka settlement) where they amounted to 0.107 and 0.620 accordingly. Hazard quotients calculated for all other chemicals (copper, zinc, cadmium, and lead) were lower than 0.1.

In 2018 total non-carcinogenic risks for adults exceeded 0.8 excluding samples taken in Kirovskiy district where the total hazard index amounted to 0.384. Maximum hazard

Table 3

Concentrations of arsenic, lead, and cadmium in examined drinking water samples and individual carcinogenic risks caused by these contaminants in 2018–2019

District		CR (children younger than 18)				CR (adults)			
		As	Pb	Cd	Σ	As*	Pb	Cd	Σ
1	2018	5.34E-05	–	–	5.34E-05	1.14E-04	–	–	1.14E-04
	2019	6.49E-05	–	–	6.49E-05	1.39E-04	–	–	1.39E-04
2	2018	3.29E-05	–	–	3.29E-05	7.05E-05	–	–	7.05E-05
	2019	6.41E-05	–	–	6.41E-05	1.37E-04	–	–	1.37E-04
3	2018	6.74E-05	–	–	6.74E-05	1.44E-04	–	–	1.44E-04
	2019	6.41E-05	–	–	6.41E-05	1.37E-04	–	–	1.37E-04
4	2018	4.52E-05	–	–	4.52E-05	9.69E-05	–	–	9.69E-05
	2019	9.53E-05	–	–	9.53E-05	2.04E-04	–	–	2.04E-04
5	2018	2.96E-05	–	–	2.96E-05	6.34E-05	–	–	6.34E-05
	2019	3.53E-05	–	–	3.53E-05	7.57E-05	–	–	7.57E-05
6	2018	2.10E-04	5.92E-07	–	2.10E-04	4.49E-04	1.27E-06	–	4.50E-04
	2019	4.03E-05	1.13E-06	1.98E-06	4.34E-05	8.63E-05	2.43E-06	4.24E-06	9.30E-05
7	2018	4.11E-05	–	–	4.11E-05	8.81E-05	–	–	8.81E-05
	2019	2.79E-05	–	–	2.79E-05	5.99E-05	–	–	5.99E-05
8	2018	4.60E-05	–	–	4.60E-05	9.86E-05	–	–	9.86E-05
	2019	6.49E-05	–	–	6.49E-05	1.39E-04	–	–	1.39E-04
9	2018	6.41E-05	5.67E-07	–	6.47E-05	1.37E-04	1.21E-06	–	1.39E-04
	2019	3.53E-05	–	–	3.53E-05	7.57E-05	–	–	7.57E-05
10	2018	8.22E-06	1.13E-06	–	9.35E-06	1.76E-05	2.43E-06	–	2.00E-05
	2019	1.64E-05	–	–	1.64E-05	3.52E-05	–	–	3.52E-05
11	2018	5.10E-05	–	–	5.10E-05	1.09E-04	–	–	1.09E-04
	2019	1.73E-04	3.08E-07	–	1.74E-04	3.72E-04	6.62E-07	–	3.72E-04
12	2018	5.84E-05	–	–	5.84E-05	1.25E-04	–	–	1.25E-04
	2019	7.23E-05	–	–	7.23E-05	1.55E-04	–	–	1.55E-04

Note: 1 is Zheleznodorozhniy district; 2 is Kyibishevskiy district; 3 is Kyibishevskiy district (Volgar'); 4 is Krasnoglinskiy district (Novaya Samara); 5 is Krasnoglinskiy district (Koshelev); 6 is Krasnoglinskiy district (Krasnaya Glinka settlement); 7 is Samarskiy district; 8 is Leninskiy district; 9 is Promyshlenniy district; 10 is Kirovskiy district; 11 is Sovetskiy district; 12 is Yuzhniy gorod.

Table 4

Total non-carcinogenic risk indexes for children and adults as per priority chemicals

Parameter	2018		2019	
	Children	Adults	Children	Adults
Arsenic				
Median	1.257	0.539	1.662	0.712
Range	0.213–5.434	0.091–2.329	0.426–4.496	0.182–1.926
10-th percentile	0.767	0.329	0.725	0.310
90-th percentile	1.747	0.749	2.472	1.059
Petroleum products				
Median	0.797	0.342	0.448	0.192
Range	0.341–1.440	0.146–0.617	0.320–1.619	0.137–0.694
10-th percentile	0.354	0.152	0.320	0.137
90-th percentile	1.215	0.521	0.852	0.365
Total coefficient				
Median	2.407	1.032	2.462	1.055
Range	0.895–7.055	0.384–3.024	1.082–5.416	0.464–2.323
10-th percentile	1.8588	0.796	1.365	0.585
90-th percentile	3.357	1.439	3.937	1.687

Table 5

Non-carcinogenic risks indexes as per specific chemicals depending on water supply sources

Parameter	2018 г.				2019 г.			
	Children		Adults		Children		Adults	
	Underground	Surface	Underground	Surface	Underground	Surface	Underground	Surface
Sulfates	0.222 ± 0.067	0.035 ± 0.009	0.095 ± 0.029	0.015 ± 0.0004	0.141 ± 0.090	0.040 ± 0.008	0.061 ± 0.039	0.017 ± 0.003
Ammonium ions	0.033 ± 0.005	0.013 ± 0.003	0.014 ± 0.002	0.006 ± 0.001	0.010 ± 0.004*	0.009 ± 0.005*	0.010 ± 0.010*	0.004 ± 0.002*
Nitrites	0.092 ± 0.08	0.001 ± 0.00	0.039 ± 0.034	0.00 ± 0.00	0.023 ± 0.023	0.001 ± 0.00	0.157 ± 0.077	0.00 ± 0.00
Nitrates	0.268 ± 0.034	0.075 ± 0.008	0.115 ± 0.015	0.032 ± 0.003	0.367 ± 0.180	0.190 ± 0.017	0.157 ± 0.077	0.081 ± 0.007

index value was also detected for water samples taken in Krasnaya Glinka settlement (3.024); as for the other districts, this parameter was lower than 1.5 there. Hazards that critical organs or systems might be damages exceeded maximum permissible levels for the central nervous system (the range was 0.125–2.347), skin (0.101–2.595), and cardiovascular system (0.096–2.347).

Just as it was the case with risks for children, the greatest contribution into total non-carcinogenic risks was made by arsenic (the median was 0.539; the range, 0.091–2.329) and petroleum products (the median, 0.342; the range 0.146–0.617). As for the districts with underground drinking water supply, significant contributions were also made by sulfates and nitrates (Table 4).

In 2019 total non-carcinogenic risks for children were higher than permissible levels in all the examined districts and were equal to those calculated in 2018 (the median was 2.462 and the range was 1.082–5.419). Total non-carcinogenic health risks for adults were also higher than permissible levels in 10 out of all analyzed city districts. Just as in 2018, hazard indexes higher than maximum permissible levels were detected for the central nervous system (the range was 0.426–4.518 for children and 0.182–1.935 for adults), skin (0.481–4.562 and 0.206–1.954 accordingly), and cardiovascular system (0.435–4.521 and 0.26–2.007 accordingly).

We assessed hazard quotients for specific chemicals that made the greatest contributions into total risk (arsenic and petroleum products) in 2019; the results were similar to those obtained for 2018 (Table 5). Sulfates and nitrates also made substantial contributions into total health risks for children and adults in districts with underground drinking water supply. We should note that there was a more apparent spread in individual risk values calculated for sulfates and nitrogen compounds in districts where drinking water was supplied from underground sources than in districts where water sources were surface ones; apparently, it indicates that drinking water quality is primarily determined by water properties at water intake points and not by conditions of water distribution networks.

In 2019 non-carcinogenic health risk for children caused by iron in drinking water was higher than 0.1 in two districts (Zheleznodorozhniy district and Kyibishevskiy district). Non-carcinogenic risks for children caused by cadmium amounted to 0.121 in Krasnaya Glinka settlement. Other individual risks calculated for chemicals didn't exceed 0.1 either for children or adults.

Although drinking water quality is still rather unsatisfactory regarding non-carcinogenic health risks, we should note that that hazard quotients values improved in some districts (Krasnaya Glinka settlement), and there was also a decrease in risks caused by nitrates and ammonium ions. It probably indicates that drinking water quality may change over time due to influence exerted by different factors.

Therefore, non-carcinogenic effects might occur due to consuming drinking water from centralized communal and drinking water supply systems. Having assessed hazard quotients as per each examined chemicals and total hazard index as well, we revealed that substantial contributions into carcinogenic and non-carcinogenic effects related to long-term consumption of examined drinking water were made by arsenic, lead, and petroleum products.

According to literature data, an issue related to underground and surface waters being contaminated with arsenic has become significant worldwide and arsenic is now seen as the gravest and most hazardous non-organic contaminant occurring in drinking water. Arsenic compounds are widely spread in natural waters due to various factors, both natural and anthropogenic ones [7–12]. Natural geochemical soil leaching contributes significantly into underground waters contamination with arsenic compounds. Surface waters can also contain arsenic in low, though detectable, concentrations (from 10 to 60 % of the total arsenic quantity) including its organic compounds, such as monosodium methyl arsenates and disodium methyl arsenates [12].

Basic anthropogenic sources that make for arsenic compounds penetrating natural waters include mining, pharmaceutical industry, glass and ceramics production, production of herbicides, pesticides, and paints, wood-processing and oil-processing enterprises, as well as metal and alloy smelting etc. [7–12].

Arsenic occurring in drinking water is the most hazardous for human health [7, 10]. It is usually revealed when water that contains non-organic arsenic compounds in insignificant concentrations is consumed over a long-term period. Arsenic occurrence is thought to cause certain chronic diseases including oncologic diseases of the urinary bladder, kidneys, and lungs; blood-vessel diseases, diseases of the lower extremities, feet, and skin; probably, it can also cause diabetes, hypertension, reproductive disorders, and disorders of children's intellectual development [7–16]. There are data on a probable relation between arsenic in drinking water and endemic goiter development [13, 14].

Approximately 1 person out of 100 who consume dirking water with arsenic contents in it being 0.05 mg/dm^3 for a long-term period may die due to an oncologic disease. This share reaches 10 % in cases when arsenic contents exceed 0.05 mg/dm^3 [7].

Basing on hazard quotients calculated for arsenic we can assume that this chemical makes a contribution into a risk of chronic diseases among people living in Samara. We should note that this assumption is well in line with a cause-and-effect relation between morbidity with malignant neoplasms among children and teenagers in Samara and soil contamination, namely with arsenic, cadmium, zinc, and petroleum products; this relation was detected by experts from the Scientific Research Institute for Human Hygiene and Ecology, Samara State Medical University of the RF Public Healthcare Ministry[6]. It is also partially confirmed by research results published in Udmurtia [17]. At the same time we should note that arsenic contents didn't exceed maximum permissible concentration (0.05 mg/dm^3) in any examined sample.

There is a recently published work [18] that dwells on analyzing health risks for employable population caused by food products contamination and there are data in it that confirm a significant contribution made by alimentary introduced arsenic into the total hazard quotient of non-carcinogenic effects produced on population health in Samara.

Lead is another priority contaminant with carcinogenic effects and it is ranked by the World Health Organization among 10 chemicals that require special attention from public health authorities and certain actions aimed at protecting health of employable population, children, and women in their reproductive age. Epidemiologic research has revealed that effects produced by lead can result in elevated risks of lung cancer, stomach cancer, and brain cancer [19]. Nevertheless, lead contents didn't exceed MPC in any examined sample and car-

[6] Sazonova O.V., Sukhachyova I.F., Drozdova N.I. [et al]. The Report on scientific research work "The Complex approach to assessing ecological and hygienic safety on Samara territory" (State registration number 01201457241). Samara, Samara State Medical University of the RF Public Healthcare Ministry Publ., 2014, 261 p.

cinogenic risks caused by this chemical were within the first or second range (negligible or maximum permissible risks).

High concentrations of petroleum products are associated with risks of acute and chronic renal failure [20, 21]. Given that, we can assume that petroleum products exert their influence on morbidity with diseases of the urogenital system in Samara; however, additional population research on the matter is required.

Total carcinogenic and non-carcinogenic risks caused by contaminated drinking water can partly make a contribution into population morbidity; however, we should take into account variable environmental impacts including ambient air and contaminants introduced with food products as well.

Our results are in line with results obtained via analyzing health risks for population in Samara; the analysis was accomplished by Rospotrebnadzor Regional office in Samara as per data obtained via social and hygienic monitoring in 2013–2017 [22].

We should stress that our research has certain limitations; primarily, a number of examined samples is too small and it doesn't allow making a representative estimation of carcinogenic and non-carcinogenic risks for the whole population in Samara. A rather short observation period is another limitation since it doesn't allow estimating whether calculated risk levels will remain the same if taken in long-term dynamics. Nevertheless, the obtained results already indicate that risks for a part of the city population are higher than permissible levels. It seems advisable to performed wider-scale controlled examinations in several regions in order to assess significance of detected factors for morbidity among population.

Conclusion. The present research dwells on assessing carcinogenic and non-carcinogenic risks basing on actual data on quality of drinking water taken from centralized drinking and communal water supply systems.

We established that maximum total hazard quotient of non-carcinogenic effects was caused by arsenic and petroleum products introduced with drinking water. Assessment of carcinogenic risks caused by contaminants introduction with drinking water revealed that total health risk for children younger than 18 corresponded to the second range as per its median value; and total carcinogenic risks for adults were within the third range that was acceptable for occupational groups and unacceptable for population in general. At the same time we should stress that arsenic contents didn't exceed hygienic standards in any examined sample. Arsenic compounds are widely spread in natural waters and considerably hazardous for human health even in relatively small concentrations in drinking water; therefore, it is vital to conduct further research on developing efficient and economically feasible procedures for water purification from this element and its compounds.

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