



Research article

## ASSESSING HEALTH RISKS ASSOCIATED WITH DRINKING WATER QUALITY (ON THE EXAMPLE OF REGIONS IN BASHKORTOSTAN WHERE OIL FIELDS ARE LOCATED)

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*Providing population with drinking water conforming to all hygienic standards is a pressing issue on territories where oil fields are located. In our research we focus on assessing water supply sources located in areas with oil fields and health risks for people who consume water from centralized water supply systems aimed at providing drinking water and water for communal use.*

*Our research goal was to hygienically assess health risks for people living in areas where oil fields were located in Bashkortostan; these health risks were caused by people consuming water from centralized water supply systems.*

*Our analysis was based on data obtained via laboratory research performed by «Bashkommunvodokanal» water supply facility and Bashkortostan Center for Hygiene and Epidemiology; the data were collected in 2016–2018 in Chishminskiy and Dablekanovskiy districts. Risks associated with drinking water quality were assessed taking into account all the requirements fixed in the Guide R 2.1.10.1920-04. Organoleptic risks related to water olfactory-reflex properties were assessed according to procedures fixed in the Methodical Guidelines MR 2.1.4.0032-11.*

*Overall carcinogenic health risk assessed in Chishminskiy and Davlekanovskiy districts was higher than maximum permissible level due to chromium<sup>6+</sup>, DDT, lindane and arsenic detected in drinking water. Population carcinogenic risks amounted to 7 additional cases for people who consumed water supplied via water intake in Alkino-2 settlement; 69 additional cases, Isaakovskiy water intake; 76 additional cases, Kirzavodskoy water intake.*

*Results obtained via non-carcinogenic risk assessment performed for all examined territories indicate that diseases might occur in the hormonal system (HQ = 3.04–4.56), liver (HQ = 2.3–3.83), and kidneys (HQ = 1.47–2.45). The highest non-carcinogenic risks were detected for people who took water from Kirzavodskoy water intake in Davlekanovskiy district.*

*We also detected unacceptable organoleptic risk (higher than 0.1) caused by excessive water hardness in Chishminskiy district.*

*All the obtained results call for developing and implementing a set of activities aimed at reducing health risks for population.*

**Key words:** health risk assessment; carcinogenic risk, non-carcinogenic risk, organoleptic risk, oil extracting industry, water supply, «Clean Water» Federal project, health risk, industrial enterprises, population health, drinking water.

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Providing population with drinking water that meets all hygienic requirements is of vital importance in areas with oil extraction, treatment and transportation [1, 2]. This is due to the fact that in these areas water intended for communal use and drinking does not meet hygienic standards [2, 3] as per a number of factors, such as hardness, manganese, iron, copper, chromium, lead, cadmium concentrations, etc.

When oil fields are exploited, aquifers are known to be adversely affected and many toxicants penetrate into ground and surface water objects. Thus, the quality of the water used for communal needs and drinking deteriorates [1–4]. For example, in the Khanty-Mansiysk Autonomous Okrug – Yugra [5], in areas with oil fields, drinking water does not meet the established hygienic requirements. Water in certain districts contains certain compounds in concentrations exceeding maximum permissible ones (MPC) including oil products (up to 2.4 times), chlorides (up to 3.9 times), bromides (up to 2.2 times), lead (up to 2 times), and cadmium (up to 3 times). In surface springs located in Perm region (Kokuyskoye oil field) [3], such compounds as xylene (up to 14 times), oil products (up to 13 times), and toluene (up to 3 times) are detected in concentrations exceeding MPC. In Saratov and Orenburg regions, underground water sources deviated from hygienic standards as per oil products, manganese, iron, total hardness, oxidability, mineralization, nitrogen and bromine compounds [6, 7].

Environmental risk assessment allows identifying primary pollutants and making decisions concerning public health. Thus, studies carried out in various regions in the Russian Federation [8–13], as well as in foreign countries [14–18], indicate that there are existing population health risks associated with drinking water quality.

People's right to have access to high-quality drinking water that meets current requirements fixed in hygienic standards is envisaged in the Federal project "Clean Water" of the national project "Ecology"<sup>1</sup>. Implementation of the project involves considering issues related to water treatment and problems with maintaining quality of drinking water in distribution networks in the existing systems. In case people live settlements that are not equipped with modern piped water supply systems<sup>2</sup>, the project envisages developing a water supply network using advanced water treatment technologies including those developed by military-industrial complex.

**The purpose** of the study was to perform hygienic assessment of health risk levels associated with the use of water from centralized water supply sources for population living in oil extraction areas located in the Republic of Bashkortostan (RB).

**Data and methods.** The study comprised two largest oil extraction districts in the Republic of Bashkortostan, Chishminsky and Davlekanovsky. The analysis was based on research materials collected in 2016–2018 and obtained from the laboratories of "Bashkommunvodokanal" and the Center for Hygiene and Epidemiology in the Republic of Bashkortostan in Chishminsky and Davlekanovsky districts. Totally, we analyzed twenty indicators for territories with developed oil industry, including 16 sanitary and chemical (Table 1) and 4 microbiological ones (total coliform bacteria, thermotolerant coliform bacteria, coliphages and total microbial count).

At present, there are 3 main water intakes in Chishminsky district: Isakovsky, Kuchumovsky and Nizhnehozyatovsky. The study was performed at the largest one, Isakovsky, which supplies water to an urban-type settlement of Chishmy and adjacent rural settlements (Ignatovka village). There are 30 operating

<sup>1</sup> Official site of the Ministry of Construction, Housing and Utilities of the Russian Federation. Profile of the Federal Project "Clean Water". Available at: <https://minstroyrf.gov.ru/upload/iblock/9a0/88020e9ed93742b78845763a395cd20e.pdf> (December 01, 2020).

<sup>2</sup> Official website of the Government of the Republic of Bashkortostan. Profile Of the Federal Project "Clean Water". Available at: <https://pravitelstvorb.ru/ru/natsionalnoe-razvitie/natsionalnye-proekty/g5.pdf> (December 01, 2020).

Table 1

## Findings on hazard rates for non-carcinogenic and carcinogenic effects development

Substance	RFD	Organs and systems	SFO
Anionic surfactants	–	–	–
Oil products	0.03	Kidneys	–
Ammonia	0.98	–	–
Total iron	0.3	Mucous membranes, skin, blood system, immune system	–
<b>DDT</b>	0.0005	Liver, hormonal system	0.34
<b>Lindane</b>	0.0003	Liver, kidneys, hormonal system	1.3
<b>Arsenic</b>	0.0003	Skin, central nervous system, cardiovascular system, immune, hormonal system, gastrointestinal tract	1.5
<b>Chrome</b> <sup>6+</sup>	0.005	–	0.42
Copper	0.019	Gastrointestinal tract, liver	–
Manganese	0.14	Central nervous system, blood system	–
<b>Lead</b>	0.0035	Central nervous system, blood system, biochemistry, development processes, reproductive system, hormonal system	0.047
Mercury	0.0003	Immune system, kidneys, central nervous system, reproductive system, hormonal system	–
<b>Cadmium</b>	0.0005	Kidneys, hormonal system	0.38
Cyanides	0.02	Nervous system, hormonal system	–
Chlorines	–	–	–
Hardness	–	–	–

Note: compounds with carcinogenic properties are highlighted in bold.

wells in the Isakovskiy water intake. Alkino-2 is a village in Chishminskiy district, where 1 water intake with 5 wells is currently operating. Bactericidal lamps are installed for water disinfection.

Communal and drinking water is supplied in Davlekanovskiy district from underground via 3 water intakes, Kirzavodskiy, Kurmankeyevskiy and Yuzhny. The study was performed at Kirzavodskiy water intake, which consists of 7 wells. Water is disinfected with bleach.

Carcinogenic, non-carcinogenic and population risks were assessed taking into account the conditions and requirements stipulated in the Guide R 2.1.10.1920-04<sup>3</sup>. To calculate carcinogenic and population risks, we made up a list of 6 compounds from groups 1, 2A, 2B according to the classification by the International Agency for Research on Cancer

(IARC) (Table 1). In order to predict risks in case there were no concentrations of certain chemical compounds, we used a 1/2 of the quantitative determination limit for a chemical compound. This technique is allowed by the risk assessment methodology. Risk acceptability was determined to be within  $1 \cdot 10^{-6}$ – $1 \cdot 10^{-4}$ .

Organoleptic properties of drinking water were hygienically assessed basing on the MR 2.1.4.0032-11<sup>4</sup>, and the list of indicators (Table 2) was selected given the limiting hazardous indicators according to SanPiN 1.2.3685-21<sup>5</sup>. According to MR 2.1.4.0032-11, the acceptable risk was equal to 0.1.

Risks related to olfactory-reflex properties of drinking water are calculated according to equations (1 and 2) taken from MP 2.1.4.0032-11:

$$\text{Risk} = \left( \frac{1}{\sqrt{2\pi}} \right) \cdot \int_{-\infty}^{\text{Prob}} e^{-\frac{t^2}{2}} \cdot dt \quad (1)$$

<sup>3</sup> R 2.1.10.1920-04. Guidelines for assessing health risks caused by exposure to chemicals that pollute the environment. Moscow, 2004. 143 p.

<sup>4</sup> MR 2.1.4.0032-11. Integral assessment of drinking water in centralized water supply systems as per chemical safety indicators. Moscow, Federal Service for Supervision of Consumer Rights Protection and Human Welfare Publ., 2011, 32 p.

<sup>5</sup> SanPiN 1.2.3685-21. Hygienic standards and requirements for ensuring safety and (or) harmlessness of environmental factors to humans. *KODEX: an electronic fund for legal and reference documentation*. Available at: <https://docs.cntd.ru/document/573500115> (December 03, 2020).

where  $\pi = 3,14$  .....;  $e$  is the base of the natural logarithm;  $d$  is differential sign;  $t$  is the confidence factor.

$$\text{Prob} = -2 + 3,32 \cdot \lg \left( \frac{\text{Concentration}}{\text{standard}} \right) \quad (2)$$

**Results and discussion.** Having analyzed data obtained via monitoring observations over drinking water quality (Table 3), we have revealed that water supplied to population on certain territories doesn't meet hygienic requirements. There is evidence that hygienic standards are violated regarding sanitary and chemical indicators (water hardness), as well as detected salts of heavy metals and compounds from the pesticide group. However, there are no deviations in other indicators, including microbiological ones, in the drinking water in the examined areas.

An assessment of individual carcinogenic risks (Table 4) has identified four compounds with their contents being higher than maximum permissible risks: chromium<sup>6+</sup>, DDT, lindane and arsenic. They are classified as

Table 2

Primary indicators for organoleptic assessment

Indicator	MPC	Criterion
Manganese	0.10	Organoleptic
Copper	1.0	Organoleptic
Total iron	0.3	Organoleptic
Chlorines	350.0	Organoleptic
Total hardness	7.0	Total indicator

Table 3

Percentage of unsatisfactory water samples by main indicators in oil extraction areas in the Republic of Bashkortostan over 2016–2018 (according to "Bashkommunvodokanal")

Territories	Fraction of samples that do not meet the established requirements (%)			
	Before entering the distribution network		Water supply network	
	1*	2**	1*	2**
Davlekanovsky	17.25	0	16.56	0
Chishminsky	21.43	0	16.67	0

Note: 1 \* means sanitary and chemical indicators; 2 \*\*, microbiological indicators.

being within the third risk range. Lead and cadmium concentrations correspond to the second risk range (maximum permissible risk).

Total carcinogenic risk rates for population health associated with drinking water in Chishminsky and Davlekanovsky districts are equal to 1.3E-03 and 1.9E-03, which corresponds to the fourth risk range and is unacceptable for all population groups. The analysis of the obtained results has shown that the greatest contribution to total carcinogenic risk rates is made by the following compounds: lindane (43.64–47.5 %), arsenic (16.21–24.16 %), chromium<sup>6+</sup> (17.53–23.7 %) and DDT (11.7–12.4 %). We should also note that the leading contribution to carcinogenic risks is made by such priority compounds as those from the pesticides group (DDT and lindane).

Population carcinogenic risk rates were equal to 7 additional cases for people using the water intake in Alkino-2; 69 additional cases, Isakovskiy water intake; and 76 additional cases, Kirzavodskiy water intake. These population carcinogenic risks rates reflect the additional (to the baseline) number of cases of malignant neoplasms that can occur throughout life (70 years) due to exposure to carcinogenic compounds contained in drinking water. Carcinogenic risk rates show only a tendency towards a change in the oncologic background which is possible under certain conditions.

The results obtained via assessing non-carcinogenic risks in chronic oral exposure to priority chemical compounds contained in drinking water are presented in Table 5. The first rank place belongs to the hazard index for the hormonal system ( $HQ = 3.04$ – $4.56$ ) due to lead, DDT, lindane, arsenic and cadmium; the second place, changes in the liver ( $HQ = 2.3$ – $3.83$ ), associated with DDT and lindane. Changes in the kidneys ( $HQ = 1.47$ – $2.45$ ) caused by oral exposure to toxicants occur due to presence of lindane and cadmium in drinking water. The highest non-carcinogenic risks have been identified at Kirzavodskiy water intake in Davlekanovsky district.

Table 4

## Carcinogenic risks for population associated with concentrations of carcinogenic hazardous compounds in drinking water

№	Indicator	Carcinogenic risk (CR)		
		CWR*, Isakovskiy water intake	CWR, Alkino-2	CWR, Kirzavodskiy water intake
1	Lead	3.02E-05	3.02E-05	1.8E-06
	Contribution (%)	2.35	2.35	0.1
2	Chrome <sup>6+</sup>	2.25E-04	2.25E-04	4.6E-04
	Contribution (%)	17.53	17.53	23.7
3	DDT	1.5E-04	1.5E-04	2.41E-04
	Contribution (%)	11.7	11.7	12.4
4	Lindane	5.6E-04	5.6E-04	9.23E-04
	Contribution (%)	43.64	43.64	47.5
5	Arsenic	3.1E-04	3.1E-04	3.15E-04
	Contribution (%)	24.16	24.16	16.21
6	Cadmium	8.0E-06	8.0E-06	1.5E-06
	Contribution (%)	0.62	0.62	0.08
Total carcinogenic risk		1.3E-03	1.3E-03	1.9E-03
Population carcinogenic risk (PCR)		69.0 (per 53037 people)	7.0 (per 5424 people)	75.6 (per 39812 people)

Note: \* means here and further CWR is clean water reservoir.

Table 5

## Non-carcinogenic risks (hazardous indices) related to drinking water quality

№	Organs and systems	(HQ) Non-carcinogenic risk		
		CWR, Isakovskiy water intake	CWR, Alkino-2	CWR, Kirzavodskiy water intake
1	Central nervous system	0.7	0.7	0.72
2	Liver	2.3	2.3	3.83
3	Kidneys	1.47	1.47	2.45
4	Gastrointestinal tract	0.7	0.7	0.71
5	Cardiovascular system	0.7	0.7	0.71
6	Skin	0.7	0.7	0.71
7	Hormonal system	3.04	3.04	4.56
8	Reproductive system	<0.1	<0.1	<0.1
9	Immune system	0.7	0.7	0.71
10	Blood system	<0.1	<0.1	<0.1
11	Biochemical changes	<0.1	<0.1	<0.1

Given numerous complaints from people about drinking water having bitter taste, an organoleptic risk analysis was carried out (Table 6). The results obtained revealed an unacceptable level of organoleptic risk (more than 0.1) associated with increased hardness of drinking water at Isakovskiy water intake in Chishminsky district. In all areas, hardness exceeded hygienic standards by 1.14–2.11 times.

Basing on all obtained data, total carcinogenic risk for people using water from Isakovskiy and Alkino-2 water intakes was 1.3E-03 and it

was within the fourth risk range (unacceptable for all population groups). We also revealed an unacceptable level of organoleptic risk associated with elevated hardness of drinking water at Isakovskiy water intake.

According to data provided by the Bashkortostan Rospotrebnadzor Office in 2018, population health in Chishminsky and Davlekanovsky districts is characterized with morbidity with certain diseases being higher than on average in the Republic: urolithiasis among the adult population, up to 2 times higher and

Table 6

## Assessment of organoleptic risk related to drinking water quality

Indicator	Value	Prob.	Risk
<i>CWR, Isakovskiy water intake</i>			
Manganese	0.052	-2.91	0.0018
Copper	0.01	-8.64	2.81E-18
Total iron	0.05	-4.656	1.61E-06
Chlorides	33.8	-5.35	4.4E-08
Total hardness	11.76	-1.253	0.105
Maximal values	–	-1.253	0.105
<i>CWR, Alkino-2</i>			
Manganese	0.05	-2.996	0.0014
Copper	0.01	-8.64	2.81E-18
Total iron	0.05	-4.656	1.61E-06
Chlorides	31.7	-5.47	2.25E-08
Total hardness	11.45	-1.3	0.097
Maximal value	–	-1.3	0.097
<i>CWR, Kirzavodskiy water intake</i>			
Manganese	0.085	-2.234	0.013
Copper	0.025	-7.318	1.26E-13
Total iron	0.05	-4.59	2.22E-06
Chlorides	40	-5.127	1.5E-07
Total hardness	21.14	-0.4064	0.34222
Maximal value	–	-0.4064	0.34222

Table 7

## A set of measures within the "Clean water" Project implementation

№	Measures	Measures within the "Clean water" project, recommended and being implemented at the moment
1	Technological and technical	– Reconstruction of a water supply network in Chishmy settlement
2	Sanitary and technical	– Construction of a drinking water purification system in the town of Davlekanovo – Improving sewage treatment and avoiding the discharge of untreated sewage – Application of additional methods for water softening – Industrial control over water quality in water intake and before it enters distribution networks
3	Administrative	– Industrial control over technical conditions of water intake facilities – Clinical examination and medical check-ups of population among risk groups (children, pregnant women and the elderly) as per the detected diseases.

for children, more than 2.5 times higher; there was also a high growth rate for this nosology between 2014 and 2018. Also, there was a 19.7 % increase in mortality rate caused by neoplasms within the analyzed period.

The results obtained are very similar to other studies published by several authors [21–25]. However, it is necessary to take into account natural peculiarities and priority contaminants typical for each area.

Given all the obtained data, we have developed a set of measures (Table 7) aimed at minimizing risks associated with the quality of drinking water in the Republic of Bashkortostan within the framework of the "Clean water" Project implementation.

When these works are completed, it is advisable to re-conduct research in order to determine whether the accomplished activities have been truly effective.

### Conclusions:

1. The total carcinogenic risks for both Chishminsky and Davlekanovsky districts have been assessed as unacceptable due to the presence of chromium<sup>6+</sup>, DDT, lindane and arsenic compounds in water.

2. High non-carcinogenic risks have been identified at Kirzavodsky water intake in Davlekanovsky district. The presence of basic compounds in water can lead to

chronic diseases of the hormonal system, liver and kidneys.

3. The organoleptic risk at Isakovskiy water intake in Chishminsky district is characterized as unacceptable due to elevated hardness of drinking water.

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