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Drinking water is the urolithiasis development factor among the rural population of a single region

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ABSTRACT

BACKGROUND: The urolithiasis incidence in the Nizhny Novgorod Region exceeds the national average that determines the importance of analyzing the causes of its development and creating preventive measures.
AIM: To evaluate the relationship between the urolithiasis incidence and drinking water composition consumed by the rural population of the Nizhny Novgorod Region.
MATERIALS AND METHODS: A chemical analysis of drinking water was performed in 50 rural districts of the Nizhny Novgorod Region (a total of 61 samples). Water was taken from centralized water supply sources, artesian wells and boreholes, and springs. The relationship between the urolithiasis incidence and chemical composition measures of drinking water was assessed.
RESULTS: Differences in the impurity content of drinking water were found between districts with different values of urolithiasis incidence. Exceeding the standard values for impurities specified in the Sanitary regulations and standards (SanPin) was most commonly detected in water from districts with the highest incidence of urolithiasis. An increase in the calcium/magnesium ratio was the most commonly noted in drinking water from these districts. In 41 (67.2%) of 61 samples, an increase of calcium level was detected. The hardness of drinking water was higher than the standard in 33.3–38.8% of samples depending on the water intake source.
CONCLUSIONS: Drinking water with a high level of hardness and mineralization is one of the etiological factors for the development of urolithiasis in Nizhny Novgorod Region. In rural areas of this region with a high incidence of urolithiasis, the monitoring of the state of central water supply sources and the impurity content in drinking water should be intensified.

Keywords: urolithiasis; stone formation; drinking water.

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Питьевая вода — фактор развития мочекаменной болезни среди сельского населения отдельно взятого региона

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АННОТАЦИЯ

Актуальность. Заболеваемость уролитиазом в Нижегородской области превышает среднероссийскую, что определяет важность анализа причин его развития и разработки мер профилактики.

Цель — оценить наличие связи между частотой мочекаменной болезни и составом питьевой воды, употребляемой сельским населением Нижегородской области.

Материалы и методы. Выполнен химический анализ питьевой воды в 50 сельских районах Нижегородской области (всего 61 проба). Забор воды осуществляли из источников централизованного водоснабжения, артезианских скважин и колодцев, родников. Оценивали зависимость между заболеваемостью мочекаменной болезнью и показателями, характеризующими химический состав питьевой воды.

Результаты. Выявлены различия в содержании примесных компонентов в питьевой воде между районами с разной заболеваемостью мочекаменной болезнью. Превышение нормативных значений СанПиН по примесным компонентам наиболее часто выявляли в воде из районов с наибольшей заболеваемостью уролитиазом. В питьевой воде из этих районов чаще отмечали повышение соотношения кальций/магний. Увеличение концентрации кальция выявлено в 41 (67,2 %) из 61 проб. Жесткость питьевой воды была выше нормативной в 33,3–38,8 % проб в зависимости от источника водозабора.

Выводы. Употребление воды с высоким уровнем жесткости и минерализации является одним из этиологических факторов развития мочекаменной болезни в Нижегородской области. В сельских районах Нижегородской области с высокой заболеваемостью мочекаменной болезнью следует усилить контроль за состоянием источников центрального водоснабжения и за содержанием в питьевой воде примесных компонентов.

Ключевые слова: мочекаменная болезнь; камнеобразование; питьевая вода.

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BACKGROUND

The incidence rates of urolithiasis (UL) vary globally from 1% to 20% and are steadily rising [1]. In the Russian Federation, the incidence of UL is also high [2–4]. Among regions, the highest rates, which exceed the national average ones, have been recorded in the North Caucasus and the Volga region [5]. At the same time, the data of the Federal State Statistics Service (Rosstat) for 2015–2021 indicate a decrease in the primary incidence of UL in 62 regions of the Russian Federation, including those in the Volga Federal District [6]. Given that the UL incidence in the districts of the Nizhny Novgorod Region exceeds the national average rates, the analysis of its causes and development of prevention measures have become important. Water with high mineralization and hardness levels is known to be one of the etiological factors of UL [7]. In our previous study, it was established that 77.5% of the districts of the Nizhny Novgorod Region were unfavorable for UL. A statistically significant relationship was found between the quality of drinking water and the number of patients with UL seeking medical advice [8].

The study aimed to evaluate the relationship between the chemical composition of drinking water consumed by the population in the districts of the Nizhny Novgorod Region and the incidence of UL.

MATERIALS AND METHODS

A study of the chemical composition of water from all 50 rural districts of the Nizhny Novgorod Region was conducted through the analysis of the following parameters: pH, color, turbidity, total dissolved solids, permanganate oxidizability, total hardness, iron, manganese, calcium, magnesium, copper, ammonium ion, bicarbonates, carbonates, and orthophosphates. Drinking water was collected from centralized water supply taps (0), private wells and artesian boreholes (1), and springs (2), in accordance with the regulatory document Sanitary Rules and Regulations (SanPiN) 1.2.3685–21, Section III [9].

Water samples were delivered in 1.0 L plastic containers to the analytical testing laboratory of BWT Barrier Rus JSC (Noginsk). Each sample was assigned a code. The temperature of the water from collection to analysis was maintained between 2 and 8°C. A total of 90 water containers were delivered to the laboratory, but this study analyzed 61 samples: 34 from central water supply sources, 18 from private artesian boreholes and wells, and 9 from springs.

Based on the previous study, out of 50 districts in the Nizhny Novgorod Region, depending on the number of medical visits for UL, 10 districts in the Nizhny Novgorod Region were classified as having the highest UL incidence and labeled as “R” (red), 29 districts with average incidence were labeled as “Y” (yellow), and 11 districts with the lowest incidence were labeled as “G” (green) [8]. Districts labeled “R” and “Y” were considered unfavorable for the UL incidence.

Statistical and analytical methods were applied in this study. Data on UL incidence in the Nizhny Novgorod Region and the Volga Federal District were obtained from official statistical reports of the Russian Ministry of Health and the Federal Research Institute of Health Organization and Informatics of Ministry of Health of Russia and individual regions for 2015–2021. Data from the reports were compiled into a summary table, followed by statistical processing and analysis using the SPSS Statistics v.26 software package. Since the data samples on the impurity content in drinking water did not meet the normality criterion, comparative analysis was conducted using the non-parametric Mann–Whitney test. The significance level for accepting/rejecting the null hypothesis (H_0) was set at $p = 0.05$.

RESULTS

The results of the comparative analysis of the chemical composition of water in districts unfavorable for UL are presented in Table 1.

The data indicate that drinking water collected in districts categorized as “R” and “Y” shows statistically significant differences in pH ($p = 0.0053$) and fluoride content ($p = 0.0369$).

A statistical analysis was conducted to examine the relationship between the frequency of patient visits for UL from the districts categorized as “R” and “Y” to the Nizhny Novgorod Regional Clinical Hospital named after Semashko and the levels of impurity components in drinking water from these districts, as well as the total values for these two district groups (Table 2).

Significant correlations in the districts unfavorable for UL were identified for such drinking water parameters as total hardness ($p = 0.0479$), calcium content ($p = 0.0453$), magnesium content ($p = 0.0323$), and bicarbonates ($p = 0.0451$). For each of these parameters, the correlation coefficients for the groups of districts were generally negative. When analyzing the content of individual components in drinking water by district and water supply point, as well as their ratios, such as calcium to magnesium, the obtained results did not meet the values recommended in the Sanitary Rules and Regulations (SanPiN).

Tables 2 and 3 indicate that differences in unfavorable conditions for UL incidence among the districts categorized as “R,” “Y,” and “G” do not correlate with specific predominant impurity components in drinking water, except for pH. However, this correlation is attributed to the relatively high levels of their total quantitative content in drinking water, considering the accompanying environmental conditions in the region. This statement is

Table 1. Comparative analysis of the impurity levels in drinking water obtained in the districts of categories R and Y, *U*-test

Таблица 1. Сравнительный анализ уровней содержания примесных компонентов в питьевой воде, полученной в районах категорий R и Y, *U*-test

Parameter group	Parameter	Differences between R and Y Districts (*p*)
General indicators	pH	**0.0053**
	Total hardness	0.1062
	Turbidity	0.2301
	Total mineralization	0.6443
	Permanganate oxidizability	0.7770
	Color	0.7385
Metals	Fe	0.5686
	Ca	0.1007
	Mg	0.0576
	Mn	0.0836
Other inorganic indicators	Ammonium ion (NH_4^+)	0.9136
	HCO_3^-	0.1123
	Carbonates (CO_3^{2-})	1.0000
	Orthophosphates (PO_4^{3-})	0.1424
	Nitrates (NO_3^-)	0.8273
	Fluorides (F^-)	**0.0369**

Note. Districts with the urolithiasis incidence: R — highest; Y — average; G — low. Statistically significant differences are highlighted in bold.
Примечание. Районы с заболеваемостью мочекаменной болезнью: R — максимальная; Y — средняя; Y — низкая. Полужирным шрифтом выделены статистически значимые различия.

Table 2. The analysis results for the correlation between the frequency of patients with urolithiasis visiting medical facility and the impurity content of drinking water in the districts of R and Y categories

Таблица 2. Результаты анализа корреляционной связи между частотой обращений пациентов с мочекаменной болезнью в лечебное учреждение и содержанием примесных компонентов в питьевой воде в районах категорий R и Y

Parameter	R districts		Y districts		R + Y districts	
	r	*p*	*r*	*p*	*r*	*p*
pH	0.3576	0.2303	**0.587**	**0.0349**	–0.3217	0.1090
Total hardness	0.2012	0.5098	**–0.628**	**0.0216**	**–0.392**	**0.0479**
Turbidity	0.0629	0.8382	–0.1145	0.7095	0.1834	0.3697
Total mineralization	0.0934	0.7615	–0.0768	0.8030	–0.0724	0.7253
Permanganate oxidizability	–0.2697	0.3729	0.1373	0.6548	0.0161	0.9380
Color (degrees)	–0.0911	0.7673	0.0673	0.8270	–0.0904	0.6606
Fe	0.0142	0.9632	–0.4136	0.1601	–0.0035	0.9866
Ca	0.1247	0.6848	**–0.580**	**0.0376**	**–0.396**	**0.0453**
Mg	0.0992	0.7472	**–0.620**	**0.0239**	**–0.421**	**0.0323**
Mn	0.2143	0.4821	**–0.5526**	**0.0501**	0.2506	0.2169
Ammonium ion (NH_4^+)	0.0692	0.8493	0.0445	0.9029	0.0501	0.8337
Hydrocarbonates (HCO_3^-)	0.2108	0.5589	**–0.935**	**0.0001**	**–0.453**	**0.0451**
Orthophosphates (PO_4^{3-})	0.3272	0.3560	–0.0140	0.9695	0.3609	0.1180
Nitrates (NO_3^-)	0.8660	0.3333	0.8660	0.3333	0.4414	0.3809

Note. *r* — Correlation coefficient, *p* — significance level. Districts with the incidence of urolithiasis: R — highest; Y — average; G — low. Statistically significant correlations are highlighted in bold.
Примечание. *r* — Коэффициент корреляции, *p* — уровень значимости. Районы с заболеваемостью мочекаменной болезнью: R — максимальная; Y — средняя; G — низкая. Полужирным шрифтом выделены статистически значимые корреляции.

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Table 3. Comparative analysis of the chemical composition of drinking water obtained from districts of different categories (R, Y and G), *p*-values

Таблица 3. Сравнительный анализ химического состава питьевой воды, полученной из районов разных категорий (R, Y и Y), *p*

Parameter	R–Y	R–G	Y–G
pH	0.106	0.441	**0.006**
Hardness	0.230	0.973	0.151
Turbidity	0.644	**0.041**	0.682
Total mineralization	0.777	0.161	0.640
Permanganate oxidizability	0.738	0.789	0.867
Color	0.569	0.100	*
Fe	0.101	0.298	0.761
Ca	0.058	0.867	0.133
Mg	0.084	0.285	0.664
Mn	0.914	0.561	0.224
NH_4^+	0.112	0.607	0.699
HCO_3^-	1.000	0.870	0.514
CO_3^{2-}	0.142	1.000	1.000
PO_4^{3-}	0.827	0.530	0.377
F^-	**0.037**	–*	–*

Note. Districts with the urolithiasis incidence: R — highest; Y — average; G — low. Statistically significant differences are highlighted in bold. *No data for comparison with category G districts.

Примечание. Районы с заболеваемостью мочекаменной болезнью: R — максимальная; Y — средняя; G — низкая. Полужирным шрифтом выделены статистически значимые различия. *Нет данных для сравнения с районами категории G.

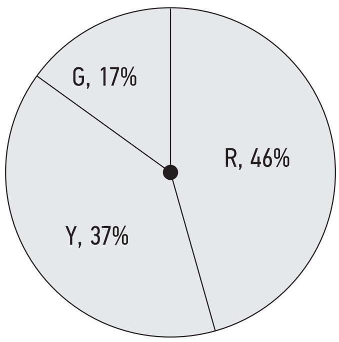

Fig. 1. Deviations from the Sanitary regulations and standards for the total impurities in water intakes of different districts categories. Districts with the urolithiasis incidence: R — highest; Y — average; G — low

Рис. 1. Отклонения от норм СанПиН суммы примесных компонентов в воде водозаборов разных категорий районов. Районы с заболеваемостью мочекаменной болезнью: R — максимальная; Y — средняя; G — низкая

qualitatively confirmed by the relative deviations from SanPiN standards for impurity components in drinking water in district centers categorized as “R,” “Y,” and “G,” presented in Figure. 1.

Figure 1 shows that the number of out-of SanPiN values for impurity components in drinking water from different types of water supply points is the highest in category “R” districts, decreasing in category “Y” districts, with category “G” districts showing a further decrease. This indicates the relative environmental well-being of category “G” districts compared to category “R” and “Y” districts.

A comparative analysis of the impurity content in drinking water from different sources was conducted depending on types of water supply points (Table 4).

The data in Table 4 indicate that water from central water supply sources (category 0) showed statistically significant differences in two parameters (total mineralization and color) compared to water from category 1 water supply points (wells, differences) and also by two

Table 4. Comparative analysis of the chemical composition of drinking water obtained from different types of water intakes, *p*-values

Таблица 4. Сравнительный анализ химического состава питьевой воды, полученной из водозаборов разных типов, *p*

Parameter	Water intake points 0–1	Water intake points 0–2	Water intake points 1–2
pH	0.970	0.059	0.190
Hardness	0.338	0.368	0.823
Turbidity	0.878	0.207	0.253
Total mineralization	**0.015**	0.297	0.332
Permanganate oxidizability	0.114	0.163	**0.011**
Color	**0.035**	0.118	**0.005**
Fe	0.925	**0.007**	**0.007**
Ca	0.244	0.402	0.823
Mg	0.215	0.316	0.551
Mn	0.856	0.286	0.336
NH_4^+	0.204	0.192	0.535
HCO_3^-	0.311	0.235	0.622
CO_3^{2-}	0.530	0.697	1.000
PO_4^{3-}	0.063	**0.032**	0.584
NO_3^-	0.439	–*	–*
F^-	0.155	–*	–*

Note. Water intake types: 0 — central; 1 — borehole, well; 3 — spring. Statistically significant differences are highlighted in semi-bold. *No data.

Примечание. Типы водозаборов: 0 — центральный; 1 — скважина, колодец; 3 — родник. Жирным шрифтом выделены статистически значимые различия. *Нет данных.

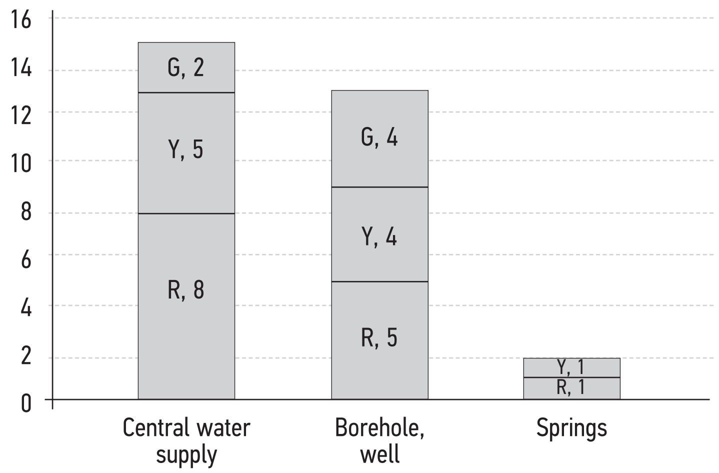

Fig. 2. Quantitative excesses of the Sanitary Rules and Regulations by drinking water impurities depending on the water intake type in the category of districts. The data are presented in absolute values. Districts with the urolithiasis incidence: R — highest; Y — average; G — low

Рис. 2. Количественные превышения норм СанПиН примесными компонентами питьевой воды в зависимости от типа водозабора в категории районов. Данные представлены в абсолютных значениях. Районы с заболеваемостью мочекаменной болезнью: R — максимальная; Y — средняя; G — низкая

parameters (iron content and orthophosphate content) compared with the water from category 2 water supply points (springs). This may be related to the depth of the corresponding aquifers of these sources. The obtained results also align with the data presented in Figure 2, where the number of out-of SanPiN values is the highest for category 0 and 1 water supply points, while the lowest number of deviations is observed in category 2 water supply points (springs). Out-of SanPiN values in drinking water parameters by district numbers from different water supply points (in absolute numbers) were identified in 15 cases in category "R" districts, 13 cases in category "Y" districts, and 2 cases in category "G" districts (Figure 2).

Thus, differences in UL incidence rates and patient visits for medical care between districts categorized as

Table 5. Drinking water hardness level depending on the type of water intake and district category (*n* = 61)
Таблица 5. Уровень жесткости питьевой воды в зависимости от типа водозабора и категории района (*n* = 61)

Water intake type / samples, *n*	District category / samples, *n*	Average hardness (mg-eq/L)	Out-of-SanPiN values, *n*	Total out-of-SanPiN values, *n*
0/34	R/8	6.07 ± 2.25	3	13 (38.2%)
	Y/20	10.89 ± 2.46	9	
	G/6	5.23 ± 1.49	1	
1/18	R/9	4.57 ± 1.18	1	6 (33.3%)
	Y/7	6.18 ± 1.61	4	
	G/2	5.92 ± 3.97	1	
2/9	R/5	4.28 ± 2.61	1	3 (33.3%)
	Y/3	9.33 ± 1.82	2	
	G/1	1.7	0	

Note. *n* — Number of samples. Water intake types: 0 — central; 1 — borehole, well; 3 — spring. Districts with the urolithiasis incidence: R — highest; Y — average; G — low.
Примечание. *n* — Количество проб. Типы водозаборов: 0 — центральный; 1 — скважина, колодец; 3 — родник. Районы с заболеваемостью мочекаменной болезнью: R —максимальная; Y — средняя; G — низкая.

"R," "Y," and "Z" are partly due to differences in out-of-SanPiN values for impurity components in drinking water from these regions. Based on quantitative differences in impurity content in drinking water from different types of water supply points relative to SanPiN limits, it was established that the dominant sources in this regard are types 0 and 1 water supply points. From the data analysis presented in Figure 2, it can be concluded that the most problematic water sources regarding out-of-SanPiN values for impurity components in drinking water are types 1 (central water supply) and 2 (wells, boreholes) water supply points, which may be related to the open form of water intake or shallow aquifers of these sources. In such cases, the specific mineral composition of these aquifers may influence their content. At the same time, no differences in water hardness levels were noted depending on the type of water supply point (Table 5).

DISCUSSION

In the Russian Federation, the overall incidence of UL decreased by 4.63% during 2015–2020 [6]. However, according to the State Report on the Sanitary and Epidemiological Well-Being of the Population in the Nizhny Novgorod Region, the incidence rate of UL in adults aged 18 years and older with a first-time diagnosis in 2019 was 143.8 per 100,000 adults, exceeding the national average of 139.9 per 100,000 adults [10]. Previously, it was established that 39 (77.5%) out of 50 districts in the Nizhny Novgorod Region were unfavorable regarding UL prevalence [8]. The population of the Nizhny Novgorod Region is supplied with drinking water from surface and underground sources. The surface water resources of the Nizhny Novgorod include the Gorky and Cheboksary reservoirs, 9,000 rivers with a total length exceeding 25,000 km, with highly heterogeneous water intake systems [11]. The impact of drinking water characteristics on UL development has long been a subject of debate. It is known that the chemical composition of water is neither altered by most of dissolved compounds, nor changes them; water acts as an inert solvent, delivering nutrients required by living cells in stable aqueous solutions [12]. Correlations between the quality of consumed water, certain anthropogenic factors, and UL prevalence have been identified by both domestic and foreign researchers [13–15]. According to SanPiN2.1.4.1074–01, the normative hardness of drinking water should not exceed 7.0 mEq/L; total mineralization should be less than 1,000 mg/L; the elemental content of water should be 0.3 mg/L or less for iron (total Fe), less than 500 mg/L for sulfates (SO), less than 0.1 mg/L for manganese (total Mn), and fluoride (F^-) should be absent [16].

The districts with the highest prevalence of UL, conventionally classified as category "R," showed statistically significant differences in hardness levels of groundwater compared with the districts classified as "Y" (moderate prevalence) and "G" (low prevalence), as based on official data sources [8, 10, 17]. According to official statistics, the condition of water supply points for wells and boreholes that are fed by underground aquifers, underground lakes, and groundwater in the districts of the Nizhny Novgorod Region is as follows: elevated water hardness in 11 districts, increased iron content in 4 districts, elevated levels of both iron and manganese in 4 districts and 2 urban areas, and elevated fluoride levels in 1 district and 1 urban area. Additionally, the average age of primary water supply stations exceeds 70 years, and the average wear of water supply networks in the region is 70% [17]. The average hardness level across all types of water intake points, as obtained in this study and presented in Table 5, indicates normal values in category "R" and "G" districts but exceeds the recommended levels in some category "Y" districts. The analysis of water from central water supplies was of particular interest due to its predominance. In 3/5 samples from category "R" districts, water hardness reached 7.5, 8.4, and 20 mg-eq/L. In 9/20 samples from category "Y" districts, hardness levels were out of recommended SanPiN limits, accounting for 45%. In category "G" districts, only 1/6 samples showed a hardness level of 9.9 mg-eq/L. Thus, hardness values were exceeded in 13/34 (38.2%) samples from type 0 water intake points; 6/18 (33.3%) samples from type 1 water intake points, and in 3/9 (33.3%) samples from type 2 water intake points (Table 5). The heterogeneity of water intake points across the districts of the Nizhny Novgorod Region is further confirmed by the fact that, since 1993, 235 licenses for the extraction of fresh underground water and 7 licenses for the extraction of mineral water have been issued [18, 19]. It has been established that the risk of UL increases fourfold when consuming groundwater with high calcium content [7]. Additionally, it is known that increased water hardness leads to greater calcium excretion via kidney tubules, thereby increasing the risk of stone formation. It has been shown that magnesium inhibits calcium oxalate crystallization in urine, and its low concentration in drinking water may increase the risk of UL. The calcium to magnesium ratio (Ca: Mg) in water is considered important. Deviations from a 2:1 ratio in favor of higher calcium concentrations increase the likelihood of stone formation [7]. Therefore, water with high magnesium and bicarbonate content is recommended for UL prevention, as bicarbonates are known to increase urine pH and prevent calcinate formation. In this study, a ratio of more than 2:1 favoring increased calcium concentrations was identified in 41/61 cases. For example, Ca:Mg ratios reached 22.1:1 (248/11.2 mg/L), 20.6:1 (13.6/0.66 mg/L), and 5.2:1 (550/104 mg/L) in category "R" districts.

In Russia, mineralization limits for bottled drinking water are regulated by SanPiN 2.1.4.1116–02, which states that total mineralization should not exceed 1,000 mg/L, with an optimal range of 200–500 mg/L. In this study, total mineralization exceeded 1,000 mg/L in six cases from water sources in category "R" and "Y" districts, reaching 1,330–2,610 mg/L. The values out of the recommended 500 mg/L limit were found in 19 out of 61 samples (31.1%), with 18 of these cases occurring in category "R" and "Y" districts. Thus, the most problematic types of water intake points were type 0 (central water supply), followed by type 1 (wells and boreholes). The challenged quality of drinking water from these water intake points could be attributed to secondary factors, such as aging of municipal water pipelines, which accumulate unwanted flora over time. The correlation coefficients between the frequency of medical visits for UL and the composition of impurities in drinking water in category "Y" districts are of particular interest (Table 2). Significant correlations were identified for impurities such as total hardness, calcium, magnesium, and bicarbonate content. For each of these, the correlation coefficients were negative. This suggests that these chemical compounds have a positive effect on the health of patients with UL, leading to fewer visits to healthcare facilities. In this group of districts, significant negative correlations were observed between the frequency of medical visits for UL and the concentrations of lightweight metal ions (Ca^{++}, Mg^{+}, Mn^{+}) in drinking water. The positive effects of trace amounts of these metals, as essential biogenic elements, are well-documented: they normalize bioelectric potential conduction in muscles and nerves, maintain osmotic pressure and cell colloid hydration, and activate certain enzymes, among other functions [12]. This type of correlation was not observed in category "R" districts, where medical visits for UL are higher than in category "Y" districts. This could be due to the presence of other impurities, such as heavy metals, which negate the effects of beneficial metal ions and increase medical visits for UL. As indicated in Table 2, comparative analysis of lightweight metal ion levels (Ca^{++}, Mg^{++}, Mn^{+}) between category "R" and "Y" districts shows that the significance level is close to the critical threshold of 0.05 for accepting the alternative hypothesis H_1, making the difference "nearly significant." Some factors contributing to UL pathogenesis can directly activate free radical processes in the kidneys. Heavy metals such as chromium, copper, iron, manganese, lead, mercury, arsenic, and zinc have pronounced toxic effects and contribute to oxidative stress. Reactive oxygen species (ROS) have been proven to generate under the influence of iron, copper, zinc, nickel, aluminum, cadmium, lead, and other metal ions [20]. Our study revealed elevated iron levels in drinking water in 4 districts, while one district reported elevated fluoride levels. People consuming such water may experience oxidative damage to lipids, carbohydrates, and proteins, as well as DNA and RNA damage, cytoskeletal disorganization, and apoptotic processes [15], creating a background for UL development or recurrence. The primary source of iron, manganese, and heavy metals in central water supplies is often outdated infrastructure. A solution at the state level would involve replacement of old pipes with plastic ones. This issue can be addressed, for instance, at the household level by installing a water filter with a function to remove iron and heavy metals.

Previously, it was found that 59.5% of the population in rural districts of the Nizhny Novgorod Region use water from underground sources, such as wells and boreholes [8]. According to official sources, the quality of water from water intake points of the Nizhny Novgorod Region depends

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on the natural composition of drinking water and its natural degradation under the influence of intense anthropogenic and technogenic exposure. These impacts are most pronounced on surface water sources, with the main pollutants being municipal utilities, energy, machinery, and chemical industries. The issue of untreated stormwater runoff from populated areas in Nizhny Novgorod Region has not yet been resolved [11]. According to the Upper Volga Department for Hydrometeorology and Environmental Monitoring, one of its functions being environmental pollution monitoring, there are over one hundred underground water contamination sites in the region, with individual contamination areas reaching up to 100 km^2 [21]. Existing pollution sources lead to changes in the quality of underground water, especially with poorly protected aquifers. Generally, the natural characteristics of the underground water in the region are primarily associated with increased hardness, turbidity, high levels of iron, and color [11]. The analysis results indicate that one of the etiological factors for the development of UL in the Nizhny Novgorod Region is the consumption of water with high hardness and mineralization levels. Based on the relatively high frequency of medical visits for UL from category "R" districts compared to category "Y" districts, stricter approaches to meeting SanPiN limits for components such as turbidity, total mineralization, color, iron content, and ammonium ions (NH_4^+), and possibly others, should be adopted. Replacement of water pipelines, search for new water intake points, and installation of household water filters could help address these issues. Most water filtration systems contain activated carbon, which also effectively removes residual free chlorine and chlorinated organic compounds used in water intake areas for disinfection. Regardless of the form in which chlorine is dosed in water treatment facilities (liquid chlorine or hypochlorite), the residual free chlorine content in drinking water should range between 0.3–0.5 mg/L, according to SanPiN 2.1.3685–21 (Section III, Table 3.13). However, it is challenging to assess its content in specific samples, including in this study, as chlorine evaporates, and analysis must be conducted within two hours of sample collection. Free chlorine can interact with organic substances in the water, forming a wide range of chlorinated organic compounds.

Since 2013, the Nizhny Novgorod Region has been included in the "Clean Water" program, which is ongoing. Official sources state that by early 2014, 72.8% of the population in the Nizhny Novgorod Region was provided with high-quality drinking water (compared with 62.1% in Russia in 2013), while 20.7% received conditionally high-quality water (compared with 72.6% and 20.4% in 2013, respectively) [11]. The "Clean Water" project in the Nizhny Novgorod Region has achieved federal state program status. Notably, one of the program's objectives includes exploratory evaluation works to ensure water supply of district centers with challenging water intake.

Due to the small volume of analyzed material and the multifactorial nature of UL genesis, the obtained results are controversial. However, the authors believe that water consumption directly plays a significant role in the metaphylaxis of UL.

CONCLUSION

Drinking water is one of the leading factors in the formation of UL among the rural population of the Nizhny Novgorod Region. The primary objectives of a comprehensive prevention and metaphylaxis program for UL in regions with water that does not meet standards should include repair and replacement of pipelines, and creation of water intake points that comply with SanPiN. Stricter monitoring of central water supply sources and impurity components in drinking water should be enforced in the districts of the Nizhny Novgorod Region with the highest UL prevalence rates. Installation of household water filters is additionally recommended in the regions with high UL prevalence.

ADDITIONAL INFO

Authors' contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study. Personal contribution of each author: O.S. Streltsova — development of the research concept, analysis of obtained data, writing the manuscript; D.P. Pochtin — collection of material, analysis of obtained data; V.F. Lazukin — statistical analysis, editing the manuscript; M.A. Kuleshova — analysis of laboratory research results, editing the manuscript.

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Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией. Личный вклад каждого автора: О.С. Стрельцова — разработка концепции исследования, анализ полученных данных, написание текста рукописи; Д.П. Почтин — сбор материала, анализ полученных данных; В.Ф. Лазукин — статистический анализ, редактирование текста рукописи; М.А. Кулешова — анализ результатов лабораторных исследований, редактирование текста рукописи.

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