University "St. Kliment Ohridski" - Bitola, Republic of North Macedonia
Faculty of Technology and Technical Sciences - Veles

Book of proceedings of the 1st International Scientific Conference - Food Science, Nutrition, Innovative Technologies and Sustainability

Veles, North Macedonia
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ASSESSMENT OF MICROBIOLOGICAL AND PHYSICO-CHEMICAL CONTAMINATION OF DRINKING WELL WATER IN THE GJAKOVA REGION

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Abstract
Groundwater near areas with agricultural land and high urban development is very much at risk of contamination. The aim of this research is to assess the quality of the well water that the local residents use for domestic and drinking purposes.During the year 2024, in the months of July and October, well water samples were collected for analysis in five localities of the Gjakova region R.Kosovo.To determine the quality of well water, the following parameters were analyzed. From the physico-chemical parameters: Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were measured using the UV PASTEL instrument for direct reading of values. From the microbiological analyses, the following were determined: Total coliform bacteria and *Escherichia coli*, using Chromocult Coliform Agar. Incubation was carried out for 24 hours:at 37 °C for coliforms and at 37 °C for *E. coli*. For *Enterococcus*, Slanetz Bartley Agar was used, and samples were incubated at 37 °C for 48 hours. The findings showed that these waters were contaminated with bacteria belonging to the genera: *Escherichia coli*, total *Coliforms*, and *Enterococcus*. Our results also showed that the number of CFU was in high positive correlations with the nutrients of the physico-chemical parameters and showed high levels of BOD and COD. According to the Pollution Load Index (PLI), it turned out that the well water was contaminated by sewage and agricultural pollution. Chemical-physical and microbiological analyses showed that the well water in the studied area does not even remotely meet local and international standards.

Key words: Groundwater, contamination, physico-chemical, microbiological, pollution

1. Introduction

Water is a fundamental element for life; therefore, its quality is essential for the health of the population and all living organisms (Yan & Cui, 2025). Ensuring safe and clean drinking water (free from harmful contaminants) contributes to improved hygiene and a reduction in waterborne diseases, particularly among vulnerable groups such as infants and the elderly (Hutton & Chase, 2017; Madamanchi, 2024). The quality of drinking water is threatened by pathogenic microorganisms, intensive agriculture (chemical usage), and other climate-related factors that depend on the implementation of sustainable management strategies (Afonso et al., 2025; Ejiohuo et al., 2024). Despite existing laws and sub-legal acts regulating the quality of drinking water, private water supply systems (wells) remain highly exposed to contamination due to the lack of systematic monitoring (Public Health Law, 2008; Law No. 04/L-147, 2021).(Berisha & Goessler, 2013)

Groundwater contamination resulting from agricultural activities, wastewater discharge, and multiple anthropogenic factors highlights the need for systematic monitoring and treatment of drinking water (Berisha & Goessler, 2013). In rural areas where centralized water supply networks are absent, well water is highly vulnerable to surface pollution, industrial discharges, and climate change (Dao et al., 2024). Poor-quality well water can pose serious public health risks; therefore, continuous water testing is essential (Lin et al., 2022; Wang et al., 2021).

1.1. Assessment of Well Water Quality in Kosovo: Challenges, Health Implications, and Standards

Ensuring access to safe drinking water in rural areas of Kosovo remains a significant challenge, as wells are continually contaminated by agricultural chemicals, industrial activities, and domestic wastewater (Çadraku et al., 2025). The identification of physical, chemical, and microbiological contaminants through the monitoring of well-water quality in the Gjakova region is essential, since communities relying on these water sources are vulnerable to waterborne diseases such as diarrhea, cholera, and typhoid fever (Charrois, 2010; Dziuban et al., 2006; Ngandwe et al., 2025; Reynolds et al., 2008). In many countries, including Kosovo, institutional monitoring of well-water quality is not systematic, and water analysis is often conducted only upon individual request; therefore, the risk of both organic and inorganic contamination remains persistent (Al-Hashimi et al., 2021; Eurien et al., 2021; Malecki et al., 2017; Zheng & Flanagan, 2017).

The objective of this study was to assess water quality based on physical, chemical, and microbiological parameters of five wells in the Gjakova region, as well as to provide education and guidance for local residents and to inform governmental authorities regarding water quality and the necessary measures to ensure access to safe and high-quality drinking water.

2. Materials and Methods

2.1. Study Area and Materials

Ten water samples, taken from five rural areas where groundwater from private wells is the main supply of drinking water and for various household uses, were examined for this study. In order to evaluate seasonal variations in water quality and determine the impact of anthropogenic and environmental factors on these groundwater resources, samples were taken during two different seasonal periods: summer and winter.

Both physicochemical and microbiological characteristics were evaluated as part of the laboratory analyses. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were investigated in relation to the physicochemical assessment since they are important markers for assessing the amount of organic load and the general quality of the water. Three primary fecal contamination indicators—total coliform bacteria, Escherichia coli, and Enterococcus spp.—were examined in the microbiological assessment. These indicators are commonly used as markers of hygienic and sanitary safety as well as the existence of biological contamination.

In order to assess the water's fitness for human consumption and to detect potential dangers to public health, the results were compared with the World Health Organization's (WHO) guidelines.

The cities and most villages of the Dukagjini region are supplied with water from the artificial lake of Radoniqi, which is located at an altitude of 440 m above sea level and which is supplied with water from the Lumbardhi River of Deqan, which source in the Albanian Alps of Kosovo.

The samples for the research were taken in the villages of the Dukagjini region that are not connected to the Radoniqi regional water supply system.

The Kosovo Agency of Statistics (2024) reports that there are 78,824 people living in the Municipality of Gjakova. The public utility firm "Radoniqi" provides drinking water to about 78% of the population, with the remaining 6% depending on other distribution networks. There is no operational water delivery infrastructure for the remaining sixteen percent of the population. As a result, the municipality's estimated 27,350 residents rely primarily on private wells for their drinking water.

This study aims to conduct monitoring of water quality in the rural areas of the Municipality of Gjakova, particularly in those locations not connected to the public water supply network. The analyses include physico-chemical and microbiological parameters, with the objective of assessing the actual condition of these water resources.

Groundwater drawn from private wells is a crucial part of the local water supply system in rural areas, acting as the main source for drinkable water and other household tasks. Additionally, these groundwater resources serve a vital role in agricultural production, especially in crop irrigation and livestock watering, while also supporting a wide range of daily activities, such as household maintenance and sanitation.

Table 1. Characteristics of the water sampling locations in the Gjakova region.

Locations	**N**	**E**	**Geological composition**	**River valley (river name)**	**Name of the watershed (Basin)**	**Indicators of pollution**
M1	42° 26'44"	20°'36'18"	Ultrabasic rocks (serpentine)	No river	Uninfluenced by rivers	Septic pits very close to the well. Lack of sewage systems.
M2	42° 28'56"	20° 31'34"	Ultrabasic rocks (serpentine)	No river	Uninfluenced by rivers	Lack of sewage systems.
M3	42° 21'18"	20° 22'8"	Ultrabasic rocks (serpentine)	No river	The White Drini River Basin	Pollution from animals, barns located near the wells. Disposal of organic manure (barn manure).
M4	42° 21'23"	20° 35'50"	Alluvial soil	Ereniku River	The White Drini River Basin	Grazing of animals in the area surrounding the well, allowing microorganisms to infiltrate during rainfall.
M5	42° 24'13"	20° 17'8"	Alluvial soil	Ereniku River	The White Drini River Basin	Use of organic fertilizers (compost, barn manure) Pollution from animals.

For the collection of water samples from wells and other underground sources for analytical testing, the ISO standard (ISO 5667-21:2010(en)) was used. This standard was applied to ensure representative samples for water quality testing.

2.2. Work methods.

To assess water quality, laboratory analyses were performed on both physico-chemical and microbiological parameters. Among the physico-chemical indicators, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were measured using the UV PASTEL instrument, which enables direct reading of values. In the absence of limit values for BOD and COD in the legal regulation of Kosovo, international guidelines from the EU Directive 2020/2184 and the WHO Guidelines (2017) were used for the assessment of organic pollution.

For the microbiological analyses, total coliform bacteria and Escherichia coli were determined using Chromocult Coliform Agar. The samples were incubated for 24 hours at 37 °C, both for coliforms and for *E. coli*. To identify Enterococcus, Slanetz Bartley Agar was used, with incubation carried out at 37 °C for 48 hours.

All samples were tested at the Hydrometeorological Institute of Kosovo in Pristina, and at the Laboratory "Sara&Meti"-Prishtina", accredited by the General Directorate for Accreditation of Kosovo.

The statistical analysis of the chemical elements and the microorganism count data was performed using SPSS 24 and PAST 5 software. Correlation and regression analyses were conducted to examine the relationships between the chemical parameters and the number of microorganisms, while the T-test and ANOVA analyses were used to assess the seasonal effects among the analyzed parameters. The graphs were generated using Microsoft Excel 2000.

3. Results and discussion

The results of this research showed that the groundwater drinking water in the Gjakova region, based on chemical analyses, had BOD and COD parameter values within the permitted limits for drinking water compared to the standards allowed by WHO/EU (BOD ≤ 3 mg/L, COD ≤ 10 mg/L) except for locality M4 where in the autumn season we have a higher BOD value (3.9 mg/L) than the limit allowed by WHO (≤ 3 mg/L), while in the summer season these two parameters were below the determined values due to the lower level of precipitation, reduced surface water infiltration and reduced minimum water dilution in this season, and because groundwater has few dissolved organic matter.

The results indicates that, although these groundwaters may be chemically and organoleptically acceptable, the fact that these groundwaters contain high levels of microorganisms makes them unsuitable for human consumption without prior treatment.

Table 2. Results of physicochemical and microbiological parameters of groundwater samples by location and season

Location	BOD	COD	E_coli	Enterococcus	Coliforms	Season
	mg/l	mg/l	[cfu/1 ml]	[cfu/1 ml]	[cfu/1 ml]	
M1	0.48	0.7	420	38	30	Winter
M2	1.18	1.12	350	125	25	Winter
M3	<0.28	<0.60	295	118	28	Winter
M4	3.9	1.22	360	70	38	Winter
M5	<0.25	<0.58	72	68	15	Winter
M1	<0.10	<0.10	40	12	12	Summer
M2	<0.12	<0.12	290	72	48	Summer
M3	<0.12	<0.12	260	89	25	Summer
M4	<0.12	<0.12	215	85	28	Summer
M5	<0.11	<0.12	135	32	34	Summer
Mean ± Std	0.56±1.17	0.30±0.48	243.7±120.3	70.9±34.2	28.3±9.91	

Based on the results of microbiological analyses, a high presence of the following bacteria was reported: E. coli, Enterococcus and Coliforms. Compared to the WHO standart for microbiological quality, these waters are not clean. The analyzed results showed that E. Coli bacteria were dominant in all sampling locations for both research seasons. Enterococcus also appeared in all sampling locations together with Coliforms bacteria for which lower values were recorded. The presence of all three groups indicates the presence of organic pollution, especially the presence of E. Coli indicates possible contamination directly from fecal discharge, where this presence was also supported by the presence of Enterococcus which testifies to a high level of fecal contamination due to its high persistence and resistance in aquatic environments, which this presence may indicate long-term (chronic) pollution levels in those groundwaters. Similarly, Coliforms, although recorded at lower values, were present at all sampling sites, confirming the continuous impact of organic pollution sources on groundwater quality.

The results show that seasonal changes affect groundwater quality, with pollution levels intensifying during winter as a result of surface runoff infiltration and higher rainfall levels.

However, microbial contamination remains present throughout the year, indicating the presence of a continuous source of contamination. These high levels are mainly attributed to the fact that this region is one of the most agricultural regions. Most of the wells are located near agricultural lands or small farms where organic manure is used for fertilization and have continuous irrigation.

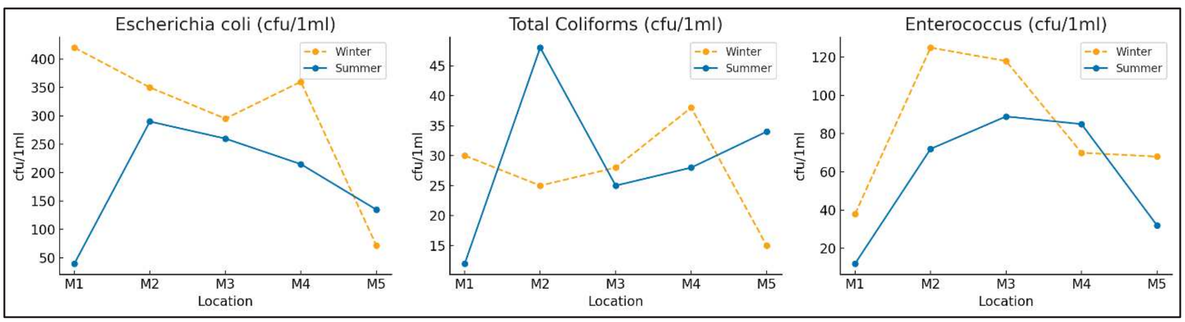

Figure 1. Seasonal variation of microbial indicators (E. coli, Total Coliforms, and Enterococcus) in groundwater across different locations.

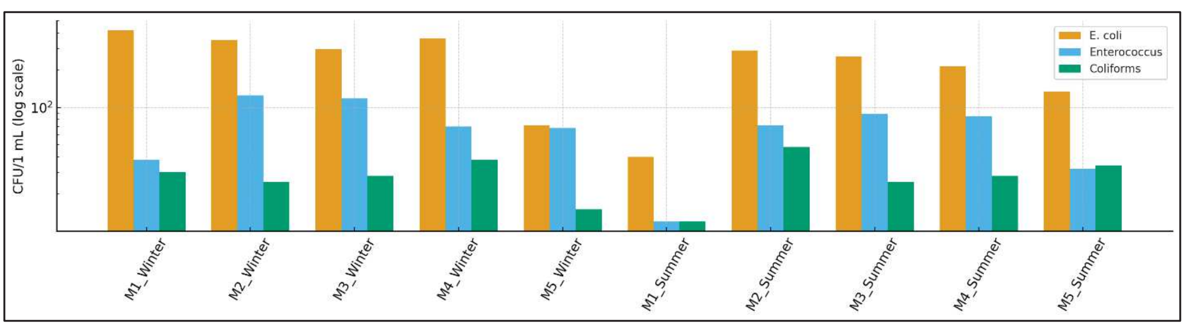

Figure 2. Seasonal distribution of E. coli, Enterococcus and Coliforms in groundwater samples (logarithmic scale).

The results showed that the chemical index values calculated from BOD and COD remain very low in all sampling locations. This is related to the fact that during the calculation of the WQI, the limits set by WHO were used, according to which the BOD values should be (<3), while COD (<10 mg/l). And this has shown that in this study in the Gjakova region the measured values were within these limits, therefore the chemical index values of the WQI were low and as reported above based on these two parameters from a chemical point of view are considered acceptable and do not pose an evident risk (table 3),

But according to the calculated WQI values for microbiological parameters compared to the WHO standard as reported above, it is required that in 100 mL of water not even one microorganism (0 CFU/100 mL) be present for the parameters E. coli, Enterococcus, Coliforms. and the deviation of the measured values from this standard has caused the microbiological index to be very high, classifying the WQI index as very poor and poor for groundwater drinking water**.**

Table 3. Water Quality Index (WQI) of groundwater samples based on chemical and microbiological indicators by season and location

Season	Location	ChemicalIndex	MicroIndex	WQI	Class
Winter	M1	0	100	70	Poor
Winter	M2	0	100	70	Poor
Winter	M3	0	100	70	Poor
Winter	M4	10	100	73	Very poor/Unsafe
Winter	M5	0	100	70	Poor
Summer	M1	0	100	70	Poor
Summer	M2	0	100	70	Poor
Summer	M3	0	100	70	Poor
Summer	M4	0	100	70	Poor
Summer	M5	0	100	70	Poor

This results that microbial factors are the primary determinants of water quality. Even though chemical criteria indicate that the water is rather clean, microbial contamination renders it unfit for human consumption unless treated beforehand.

Biochemical Oxygen Demand BOD and Chemical Oxygen Demand COD, two indicator of organic pollution in water, demonstrated a high positive association ($\beta = 0.84$; $p < 0.01$) according to correlation analysis results (Figure 3). These two parameters showed moderate correlation and regression values with microbiological indicators (E. coli, Enterococcus and Coliforms total) where COD showed stronger correlation and moderate regression with E. coli ($\beta = 0.67$; $p < 0.05$) and low regression values (R=0.24). While Bod showed low correlation and regression with E. coli ($\beta = 0.47$; $p < 0.05$), (R=0.13) (Figure 3 and 4), with total Coliforms ($\beta = 0.30$; $p < 0.05$) and moderate regression values (R=0.54), also with enterococcus it showed low correlation ($\beta = 0.11$; $p < 0.05$) and very low regression (R=0.01) (Figure 3 and 4). These relationships show that microbiological pollution is greatly influenced by other factors, such as infiltration of wastewater or organic fertilizers from agriculture, which also affect increases in COD and BOD value.

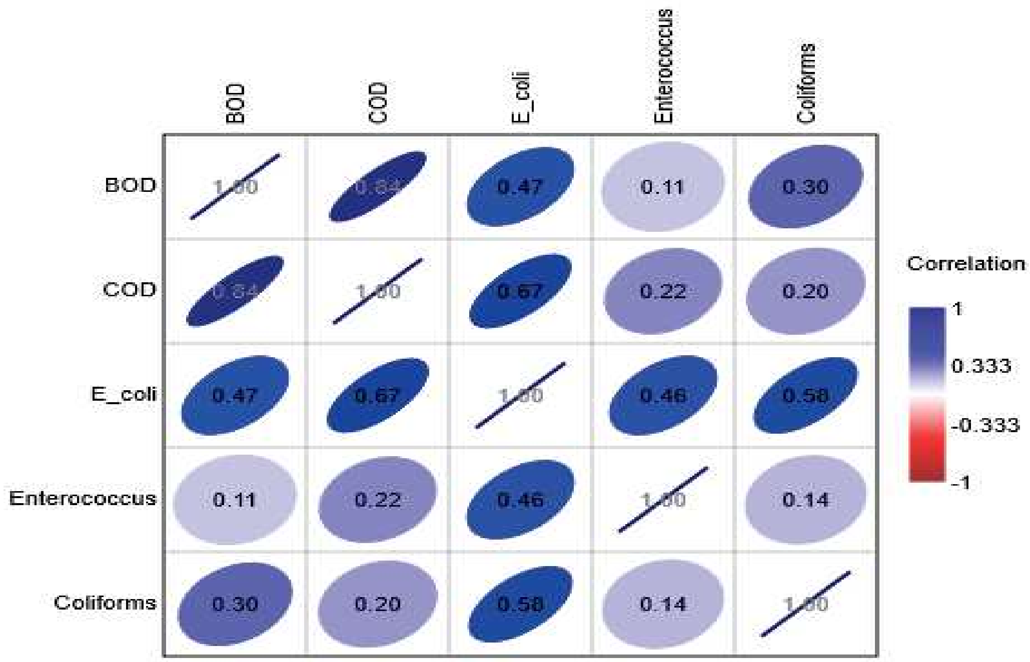

Figure 3. Correlation matrix in a groundwater samples between microbiological indicators (E. coli, coliforms, and enterococcus) and physicochemical parameters (BOD, COD)

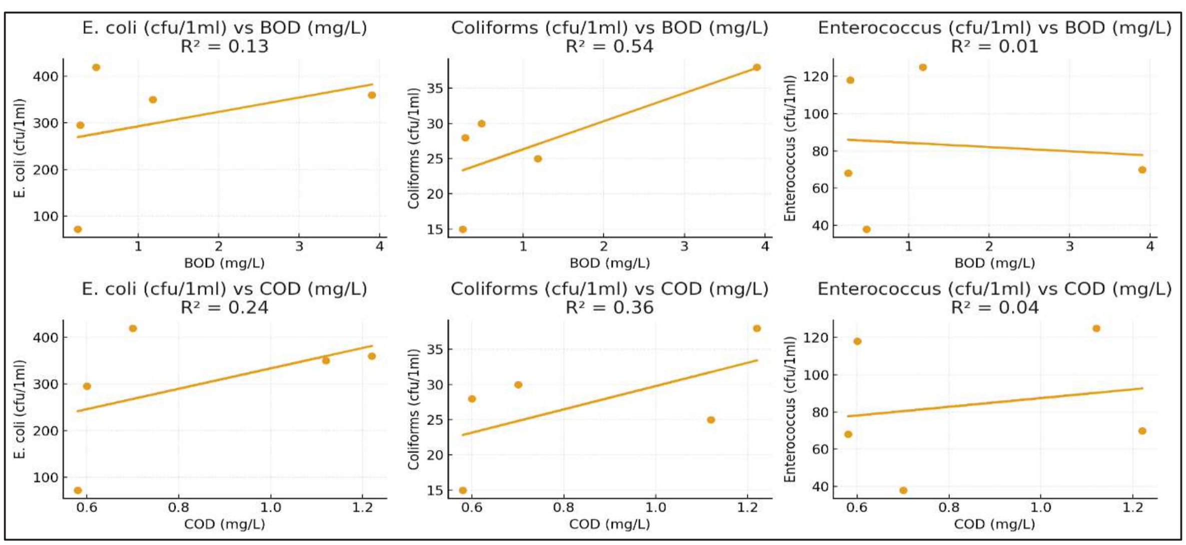

Figure 4. Regression in a groundwater sample between physicochemical parameters (BOD, COD) and microbiological indicators (E. coli, coliforms, and enterococci).

The results of the T-test and ANOVA showed that the analyzed parameters BOD, E. coli, Enterococcus and Coliforms, did not show statistically significant differences between the analyzed seasons ($p > 0.05$). However, based on the ANOVA, statistically significant seasonal changes were reported only for the COD parameter ($p = 0.0496$), indicating that COD is more sensitive to seasonal changes (Table 4).

Table 4. p-values for seasonal differences (Winter vs. Summer)

Parameter	t-test p-value	ANOVA p-value	Significance
BOD	0.202	0.166	Not significant
COD	0.0819	**0.0496**	Significant (ANOVA only)
E. coli	0.180	0.178	Not significant
Enterococcus	0.284	0.284	Not significant
Coliforms	0.762	0.760	Not significant

The findings of this study revealed that the microbiological quality of well water in the Gjakova region was of significant concern due to the elevated concentrations of *Escherichia coli*, *Enterococcus*, and total coliforms, despite the chemical parameters largely remaining within acceptable limits. Comparable results were reported in the neighboring Tetovo region (Durmishi et al., 2022), where the primary issues were attributed to microbiological variations, whereas chemical parameters were generally within permissible thresholds. According to international studies conducted in the United States (Malecki et al., 2017; Millner et al., 2025; Peer et al., 2024), private wells continue to be extremely vulnerable water supplies. They are frequently left unguarded and infrequently monitored by institutions, which is similar to the situation in Gjakova. Similar to this, (Bretcan et al., 2022) showed that since fecal contamination is the main health risk, microbiological studies must be included in the evaluation of groundwater quality at the European level. These similarities make it abundantly evident that wells as a source of drinking water present universal difficulties, and our findings align with both local and global realities.

4. Conclusions

This study showed that the microbiological quality of the well water in the municipality of Gjakova was concerning, even if the chemical parameters were largely within the acceptable ranges established by national and international regulations. The levels of fecal markers, such as Escherichia coli, Enterococcus, and total coliforms, in all water samples were much higher than the WHO and EU thresholds of 0 CFU/100 ml.

Based on the Water Quality Index (WQI) from a microbiological perspective, the well water was classified as "poor" and unsafe for drinking. Statistical analyses revealed that the organic pollution parameters (BOD and COD) had a positive correlation with the microorganisms, suggesting that organic loads from wastewater and agricultural waste directly affect the microbiological pollution of groundwater. Meanwhile, Enterococcus emerged as an indicator of chronic and long-term fecal pollution, regardless of the measured organic load.

The fact that contamination is present year-round and gets worse in the winter suggests that the sources of pollution are permanent and closely related to farming, the use of organic fertilizers, and the absence of sewage infrastructure.

These findings underline that groundwater wells in this region are unsafe for human consumption without prior treatment. In addition to implementing preventive steps to limit pollution and raising public knowledge of the health dangers associated with drinking water from private wells, regular monitoring by the appropriate authorities is necessary. Additionally, to enhance water quality and protect public health, disinfection techniques like chlorination are advised.

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