*Nature & Science*
February 2026, Vol. 8, Issue 1, pp. 53–57
DOI: https://doi.org/10.36719/2707-1146/64/53-57

# The Impact of Natural and Anthropogenic Factors on the Microbiological Quality of Groundwater

**Fatima Jafarova**

***Abstract.*** *Water, considered the «source of life» of humanity, is one of the most important resources. The quality of drinking water is important for human health, environmental protection and economic development. Freshwater is a limited natural resource. With population growth and intensifying anthropogenic impact, the problem of the quality of underground and surface water resources is becoming increasingly acute, since these waters serve as primary sources of drinking and domestic supply.*

*The quality of groundwater is controlled by a combination of natural processes and human activities. Natural factors include the interaction between water and rocks, soil leaching, precipitation infiltration and hydrological and biological processes that affect pH, mineralization, and overall hydrochemical composition of water. These processes define the natural background conditions of groundwater quality and vary depending on geological settings and climatic conditions.*

*At the same time, anthropogenic impacts significantly alter groundwater quality. Agricultural practices involving the application of fertilizer and pesticides supplement, urban expansion, industrial activities and the discharge of untreated or insufficiently treated domestic wastewater contribute to increased concentrations of nutrients, heavy metals and pathogenic microorganisms. Inefficient water management practices further exacerbate these impacts, leading to degradation of groundwater resources and increasing risks to human health and ecosystem stability.*

***Keywords:*** *groundwater, natural factors, anthropogenic impact, surface water, sustainable water management*

## Introduction

Water is a vital natural resource that supports human health, ecosystem activities and economic development. Although water covers about 71% of the Earth's surface, only a small part of it is present as fresh water for direct human use. Therefore, surface and groundwater play an important role in drinking water supply, agriculture and industry. Population growth, urbanization and climate change increase the pressure on these resources and generate growing concerns about the deterioration of water quality (World Health Organization, 2022).

Microbiological contamination has become a serious water quality problem, especially in regions with poor sewage and wastewater treatment infrastructure. Point and untreated sources of pollution, including rainwater and untreated wastewater, can significantly disrupt the physical, chemical and biological integrity of water systems (Bartram & Ballans, 1996).

Baku State University, Master student, Baku, Azerbaijan
E-mail: jafarovafatima03@gmail
Received: 22 October 2025; Accepted: 11 January 2026; Published online: 25 February 2026
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Contamination can lead to water-borne diseases, including diarrhoea, cholera and typhus, posing serious public health risks, especially to vulnerable populations. While natural filtration processes in wetlands, soil and aquatic systems can reduce microbial load, their effectiveness largely depends on local hydrological regimes and seasonal variability (Lenart-Boroń et al., 2017).

Previous studies have evaluated the microbiological quality of water depending on natural or human factors, however, the combined effects of area use, hydrogeology and human activities on microbial groundwater contamination have been systematically studied by few. The distinguishing between natural background conditions and anthropogenic impacts is very important for the development of effective water management and conservation strategies. Therefore, the purpose of this study is to assess the impact of natural and anthropogenic factors on the microbiological quality of groundwater in various types of land use, including in urban, rural and pasture areas. The study, combined with hydrogeochemical and microbiological analysis, aims to identify the main determinants of water quality change and provide evidence-based recommendations for sustainable water basin management.

This study aims to evaluate the influence of natural and anthropogenic factors on the physicochemical and microbiological quality of surface and groundwater. The object of the study is water resources formed under conditions of various land uses, including rural and urban areas, where natural processes and human economic activities have a complex impact on water quality. The main objective of the study is to identify the key determinants of spatial and seasonal variability in water quality indicators, as well as to distinguish between the natural hydrochemical background and pollution caused by anthropogenic loading. Microbiological indicators are emphasized because they are sensitive indicators of contamination and represent a potential threat to public health (Mao et al., 2023)

The study also analyzes the role of hydrological processes such as precipitation, surface runoff and infiltration in the transport and transformation of pollutants. An integrated approach based on a combination of physicochemical and microbiological indicators allows us to deepen our understanding of the processes of water quality formation and to substantiate scientific recommendations for the sustainable management of water resources.

## Materials and Methods

1. *Research area and sampling place*

The study was carried out to evaluate the effects of natural and anthropogenic factors on the microbiological quality of groundwater in various types of land use, including in cities, villages and grasslands. Sampling points include wells and boreholes that open aquifers in fractured or porous rock formations with conventional groundwater sources. To evaluate the state of the natural background, sampling points were selected in areas with minimal anthropogenic impact. Soil samples were collected near water sources to characterize possible sources of contamination (Baird et al., 2013).

2. *Sampling procedure*

Groundwater samples were periodically collected to reflect temporal variations, including dry and wet periods. Sterile containers were used and samples were transported to the laboratory under refrigerated conditions (4 °C). Soil samples from the top 0-25 cm layer were collected in triplicate at each site. Samples were dried, homogenized and sieved (<2 mm) prior to chemical analysis (Rao et al., 2022).

3. *Hydrogeochemical analysis*

Physicochemical parameters such as temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), total amount of dissolved solids (TDS) and salinity were measured in situ with portable multiparametric devices. Water samples for laboratory analysis are

filtered (0.45 microns), acidified with nitric acid for cationic analysis and stored in polypropylene bottles. The major ions were analyzed using ion chromatography. The composition of the isotopes (approx. $\delta^{18}O$ approx. $\delta^{2}H$) and isotopes of sulfates (approx. $\delta^{34}S\text{-}SO_4$, approx. $\delta^{18}O\text{-}SO_4$) by means of mass spectrometry of isotopic ratios to evaluate the origin of the water and the possible sources of contamination. Radon activity in groundwater ($^{222}$ Rn) was measured in the field with an in-field radon monitor (RAD7) (Liu et al., 2023a).

4. *Microbiological analysis*

The microbiological quality of groundwater was evaluated using selective and differential means for selective and differential media for various bacteria, including sulfite-reducing clostridia, including common coliform bacteria, fecal coliform bacteria, enterococci, Pseudomonas spp. andsulfite-reducing clostridia.

The following selective and differential media were used:

Chromocult Coliform Agar – Total number of coliform bacteria and E. coli

McConkey Agar – Gram-negative bacteria that ferment lactose

Lactose Tergitol 7 Agar – fecal coliform

Plate Count Agar (TTC) – the total number of heterotrophic bacteria

Bile Aesculin Azide Agar – Enterococci

Slanetz and Bartley Agar – Enterococci enumeration

Cetrimide agar – Pseudomonas spp.

TSC Agar – sulfite-reducing clostridia

All products were incubated according to recommended conditions and bacterial colonies were calculated in CFU/100 ml according to standard water quality standards (Lyons et al., 2023).

5. *Soil analysis and Statistical Treatment*

Soil samples were analyzed for pH, organic matter and metallic traces such as iron and manganese. Acid acid digestion (aqua regia) was used to analyze the metals, then atomic absorption spectroscopy (AAS). Soil properties were analyzed to evaluate their potential contribution to groundwater contamination though leaching and water-rock interaction (Subramaniyan & Elango, 2024).

Data from hydrogeochemical, microbiological and soil analyses were collected and processed using statistical and multidimensional approaches to determine the relationship between natural and anthropogenic factors and groundwater quality. Hierarchical clustering analysis (HCA) and correlation analysis can be applied to identify relationships between water quality parameters and to distinguish between natural and anthropogenic influences on groundwater quality.

**Results and Discussion**

The assessment of groundwater quality for different types of land-use conditions indicates that microbiological pollution occurs under the combined influence of natural environmental factors and anthropogenic activities. The main role in the distribution and abundance of microbiological indicators in underground water systems is played by differences in land use patterns, hydrogeological conditions and seasonal patterns.

Microbiological indicators such as total coliforms, fecal coliforms, enterococci, Pseudomonas spp., and clostridia, which reduce sulfite, are widely used to assess groundwater sanitation and safety. Their presence in groundwater reflects both recent episodes of pollution and the long-term impact of land use factors. Increased concentrations of coliform bacteria and enterons are most commonly associated with agricultural activities, animal husbandry, and infiltration of untreated or insufficiently treated domestic wastewater. This confirms the high sensitivity to microbiological contamination of shallow water layers and groundwater filling areas (Lyons et al., 2023).

Seasonal variability represents an additional factor affecting groundwater quality. Increased precipitation and surface runoff during periods of high humidity contribute to the transfer of

pollutants from soils and surface sources to groundwater through infiltration processes. In dry periods, on the contrary, a decrease in dilution and an increase in the duration of water stay in the water layer can lead to the continuation of microbiological contamination. This seasonal trend highlights the need to consider climatic conditions when interpreting groundwater quality data (Wang et al., 2024).

Natural hydrogeological factors also make an important contribution to the formation of the microbiological state of groundwater. Granulometric composition of soils, composition of organic substances and mineral composition of rocks determine filtration properties of environment and survival at migration of microorganisms into underground horizons. In areas with favorable geological conditions, natural self-cleaning processes can reduce microbiological stress, but with high anthropogenic stress, their effectiveness is often insufficient (Zhang et al., 2024).

A thorough analysis of microbiological and physicochemical indicators makes it possible to more fully understand the processes of formation of groundwater quality. The application of multitasking statistical methods such as hierarchical cluster analysis and correlation analysis helps to identify examples and associations between water quality indicators and potential sources of pollution. Such an integrated approach is necessary to distinguish between the natural hydrochemical background and pollution of anthropogenic groundwater.

In general, the discussion shows that groundwater quality cannot be explained by the influence of one factor. It is formed as a result of a complex interaction of land use, hydrogeological conditions, seasonal variability and anthropogenic activity. The findings highlight the need to implement comprehensive groundwater monitoring and management programs, taking into account both natural processes and anthropogenic pressure, to ensure long-term safety and sustainable use of groundwater resources.

## Conclusion

The study assessed the influence of natural and anthropological factors on the microbiological quality of groundwater under different land use conditions, including urban, rural and grazing areas. The analysis shows that groundwater quality is determined by the combined effects of hydrogeological environments, soil characteristics, seasonal variability and human activities. Land use practices and proximity to potential sources of contamination play a key role in determining the presence and distribution of microbiological indicators, such as coliform bacteria, enterococci, Pseudomonas spp. and sulphite-reducing clostridia (Wang et al., 2024).

The results underline the need to consider both natural background conditions and anthropogenic pressures in assessing the safety and vulnerability of groundwater. An integrated approach combining microbiological and physicochemical indicators is essential for a comprehensive groundwater quality assessment. This approach can support informed decision-making in water resource management (Ravindiran et al., 2023).

Overall, this study highlights the importance of sustainable groundwater protection strategies, including regular monitoring, protection of charging areas and reduction of sources of anthropogenic pollution. Future research should focus on long-term and seasonally resolved assessments to improve understanding of groundwater pollution processes and increase the effectiveness of groundwater management and protection practices.

## Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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