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Research Article

THE USE OF WELL WATER AND THE IMPACT OF MICROBIAL CONTAMINATION ON PUBLIC HEALTH

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Abstract
In the region of Shkodra, private wells serve as a source of water for some families, both in urban and rural areas, for many activities. The main purpose of this study was to comprehensively assess the microbial quality of well water, with the aim of understanding its potential impact on public health among populations who use this water for daily consumption. The study included 10 monitoring stations during the period September 2023 to August 2024 with a total of 80 water samples were analysed, for *Intestinal enterococci* and *Escherichia coli.* The application method for microbiological use of well water is that of the ISO membrane filter ISO7899-2:2000, SM 922 B-2015. *Intestinal enterococci* dominated in 65% of the samples. As for the water source diseases encountered by residents, *E. coli* infections dominate with 90.36%, *S. typhimurium* 8.36%. From the correlation analysis result *Escherichia coli disease* correlates 80% with the presence of *Intestinal enterococci* in well water and 80% presence of *Escherichia coli disease*. The results of this study demonstrate that the high presence of pathogens in well water poses a risk to public health. Well contamination is mainly caused by untreated wastewater, nearby septic tank, animal waste. The novelty of this study lies in the fact that, for the first time, a correlation was applied between the microbial contamination of well water and the diseases resulting from its use, thereby confirming the relationship between water quality and public health.

Keywords: Diseases, *Escherichia coli*, *Intestinal enterococci*, Public Health, Well Water

INTRODUCTION

Drinking water is essential for health and a legal right to equality (WHO 2008). Water is a vital resource for human life, being essential for human survival and for all productive activities in the development of society (Cosgrove & Loucks, 2015; Ajadi & Ayanlowo, 2025). Water as a vital resource for the life and well-being of the global population is important to monitor and analyze (UNESCO & UN Water, 2020).

Groundwater is mainly an important source of drinking water for people (Salman et al., 2019; Alkilany et al., 2025; Tanti et al., 2025). Water is one of the largest resources used by a large number of people and one of the most common sources of infectious diseases. For this reason, water quality is the most important factor to guarantee public health (Madigant et al., 2010; Asmaningrum et al., 2025; Tanti et al., 2025). Ensuring access to safe drinking water continues to pose a major challenge to public health (Ernias et al., 2024). According to a report published by UNESCO and released at the UN Water Conference 2023, about 2 billion people (26% of the population) do not have access to safe drinking water, while 3.6 billion (46%) do not have managed sanitation safely. Various diarrhoeal diseases account for almost 3.6% of all serious diseases on a global scale, emphasising the importance of drinking water safety (C.J. 2012; Clasen, 2015; Tanti et al., 2021; Charlize et al., 2025). Chemical pollution present in water usually does not cause immediate and severe effects on human health. For this reason, microbiological pollution is considered much more important for study, which continues to be the main cause of disease and mortality as a result of exposure to polluted water (Villanueva et al., 2014; Tanti et al., 2021; Demon & Santos, 2025; Diaz et al., 2025).

Extreme weather events such as flooding can negatively affect well water quality. Floodwaters can seep into groundwater layers, affecting the contamination of borehole water sources and making it unsafe for use. This can increase the risk for health and environmental problems (WHO 2009). The pollution of surface and underground waters with various chemical substances as a result of industrial development, poor agricultural management, and waste disposal constitutes a major problem for access to safe water sources. (Beegum et al., 2020; Chmielewski et al., 2020a; Mishra et al., 2021; Kurniawan et al., 2022; Fetmirwati et al., 2025).

Most of the studies conducted have focused on the quantity of water, paying very little attention to the quality of water (Van et al., 2017; Hafiz et al., 2025; Hagad & Riah, 2025). About 71% of the earth's surface is surrounded by water (Eslamian et al., 2018). Albania is considered one of the richest countries in Europe in terms of water resources, of which 65% originate within the country and 30% are groundwater. (Miho et al., 2013; Lushaj et al., 2016). But drinking water is not used everywhere, which is covered by the water supply network, which is provided by the water and sewerage companies. In rural areas, but also in private urban areas, it can be used as drinking water, the water from the wells. The wells are monitored from time to time by competent health laboratories, due to the way they are constructed and managed, they are easily contaminated by both natural sources and human activities. The use of methods and accurate analysis of data positively informs and protects the quality of well bridges and their daily care (Islami et al., 2025; Jackson & Alfaki, 2025; Sutiani et al., 2025).

Such policy-making in other areas such as tourism should also take the real conditions on the ground, including the appearance of water resources. (Muhamad et al., 2025). Likewise, the composition of the aquifer has a significant impact on the penetration of pollutants from barriers that can prevent the passage of pollutants into groundwater from surface runoff, atmospheric precipitation, etc., threatening the safety of groundwater (Duan et al., 2023; Klinaku et al., 2025; Linh et al., 2025). Escherichia coli is frequently present in water sources that are vulnerable to fecal contamination, including wells constructed outside of established standards and surface waters (Bain et al., 2014; Bain et al., 2021). *E. coli* is one of the most important indicator pathogens of contaminated water (Jang, 2017) This bacterium is naturally found in the intestinal flora, but its presence in water poses a risk to public health and it can persist and grow over time in various aquatic habitats, among others (Devane et al., 2020; Le & Aye, 2025; Nisa et al., 2025). As a result, they have an impact on public health due to the presence of pathogenic microorganisms that penetrate into these underground waters. In this paper, we have analysed the water of wells located near surface waters such as lakes, rivers, seas, and lagoons.

For all these issues, the analysis of the correlation between microbial contamination of well water and the diseases they cause will help us to understand the sources of pollution and the levels of pollution. It will also help us to identify wells in the most at-risk areas in order to monitor them more frequently and take preventive measures. Based on scientific knowledge, a special mechanism can be created for controlling the quality of water in wells, which would enable the collection of information on the presence of harmful microorganisms and the assessment of the consequences in the community (Susbiyanto et al., 2024). The results collected in similar works like ours showed that the analysis of microbial contamination of well water is an important indicator that shows information related to risks to public health (Cfarku & Berdufi, 2024). Areas where processing industries are located cause pollution that accumulates in the environment and can be absorbed by living organisms, affecting health (Febriansyah et al., 2024). The rapid expansion of data on water pollutants but also on-air pollutants and climate change, especially in relation to public health, presents both opportunities and challenges for traditional epidemiology (Majeed et al., 2024; Mor, 2025; Rahajo & Kumyat, 2025; Saindah, 2025).

Also, the variation in different seasons will help us to understand which are the most dangerous periods in order to plan more frequent monitoring in those periods, such as rainfall or discharge of pollutants or fertilisers. Based on the location and use of their water by the number of users and why the waters of these wells are used, it will help us to understand the possible risks that they may bring to public health.

The study will also focus on their infrastructure, since depending on the construction and maintenance of wells, priority will be given to those with the weakest infrastructure, which will undoubtedly be given priority in studies and recommendations for analysis of their microbial quality. All these hypotheses put forward in this detailed study will make it possible to identify the microbial risk of the well water taken into study and will help in contemporary strategies for their management. Since this study is being conducted for the first time and is the only one on dependence with concrete analyses, water quality and diseases, the information will be useful in improving the water management programmes of well owners and many institutions, as well as improving water quality and protecting public health.

RESEARCH METHOD

This study represents analytical and descriptive research during a 1-year period, September 2023-August 2024, in the Shkodra region of Albania. The main objective of the study was to assess the microbiological quality of well water in several different locations and the impact of microbial pollution, pathogens in water, on public health, through the correlation of epidemiological data related to water-related infectious diseases. The methodology used for microbiological parameters was analysis using the membrane filter method. The novelty of the study was related to its main objective, which was a detailed and long-term analysis in the Shkodra region along the lake, the Buna river, the Velipoje sea and the Viluni lagoon, in private areas and businesses, between bacterial indicators and water-related diseases, concluding based on the correlation between them. It was a comprehensive analysis carried out for the first time in this northern region of Albania, with different microenvironments and microclimates, accompanied by important recommendations. Well water sampling was performed according to ISO 5667-5:2006, sample storage and transport according to ISO 5667-3:2018 The correlation analysis used was Spearman correlation matrix. The correlation is performed using symbolic programming language MATLAB R2024b.

The study was carried out in the region of Shkodra, Albania. Water samples were analysed from 10 well stations located in different locations near water sources such as lakes, rivers, seas, and lagoons (Fig. 1). In wells 1 and 2, they are built near the lake of Shkodra, in Shiroka, a very populated area, especially during the tourist season. Wells 3, 4, 6, 7, and 8 are built on the side of the Buna River. Well 5 built near the river Drin. While well 9 was build near the Adriatic Sea, Velipoja and well 10 was built near the lagoon. The selection of wells was made based on their proximity to pollution sources such as urban areas, waste dumps, proximity to septic tanks and agricultural activities. This selection was made due to the fact that wells located near these sources, pollutants can more easily penetrate the wells. The way in which the water from these wells is used, mainly for drinking water, was also taken into consideration

The analyses were carried out during four different seasonal periods, specifically autumn 2023, winter 2023, spring 2024, and summer 2024. For each season, 10 stations were analysed for the two bacterial indicators, *Escherichia coli* and *Intestinal enterococci*, for a total of 80 analyses for the two bacterial indicators analysed. The samples were analysed in the laboratory of the Faculty of Natural Sciences in the Department of Biotechnology, Tirana.

Table 1. Geographic coordinates of the sampling stations taken in the well water study

Station code	Sampling stations	Geographic coordinates
P1	Lake- Shiroka	42°03'36.3"N 19°26'58.9"E
P2	Lake- Shiroka	42°03'33.7"N 19°27'17.8"E
P3	Plant	42°03'15.6"N 19°28'40.7"E
P4	Buna River	42°03'16.6"N 19°29'14.6"E
P5	Berdice	42°01'52.3"N 19°29'48.2"E

Station code	Sampling stations	Geographic coordinates
P6	Darragjat	42°00'05.7"N 19°27'28.0"E
P7	Reç i Ri	41°54’51.3"N 19°21’32.7"E
P8	Pulaj	41°52'23.1"N 19°22'50.2"E
P9	Velipoja Sea	41°51'48.6"N 19°25'08.6"E
P10	Viluni Lagoon	41°51'43.9"N 19°26'50.3"E

Figure 2. Positive sample with *Intestinal enterococci*

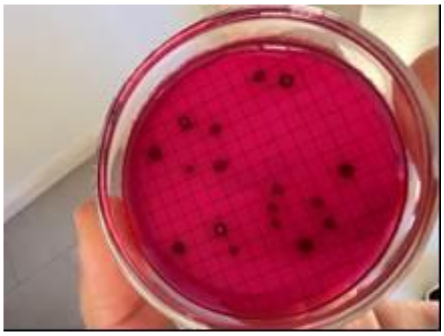


Figure 3. and *Escherichia coli*

Endo-agar medium at 44.5°C for 48 hours was used for the determination of *Escherichia coli*. The sample was positive when the colony showed a metallic sheen (SM 9222 B-2015). The endo agar medium has been successfully tested in many different countries, which has given very good results (Grabow et al., 1979; Rice et al., 1987). Several methods are used to identify pathogenic bacteria such as, *Escherichia coli, Shigella, Shigella flexneri,* and *Salmonella typhimurium,* causing waterborne infectious diseases. The collection of data on diseases was carried out in collaboration with the Shkoder Public Health, where the results of the relevant disease analyses were obtained from the physical registers at this institution.

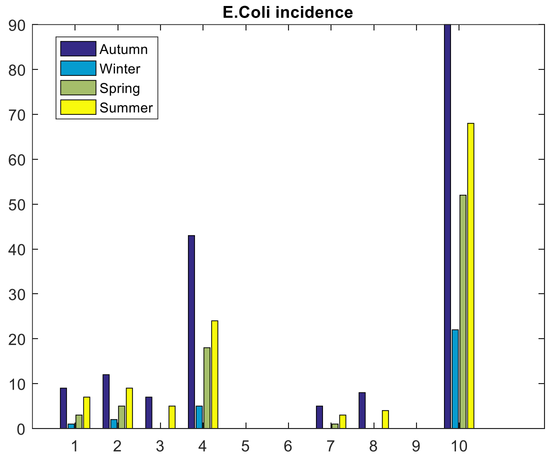
For the identification of *Escherichia coli,* the endo agar medium is used, incubating for 24 hours at a temperature of 37°C (Hohmann, E.L. 2001; Medeiros, M. et al. 2001). Deoxycholate -citrate-agar medium is used for the identification of *Shigella* and *Salmonella typhimurium*. After 48 hours, if the sample is positive for *Shigella,* small, dark colored colonies are formed. (Leifson et al., 1935). For further identification, biochemical characteristics were used, where for *Shigella* and *Salmonella typhimurium*, colonies were placed in tubes containing Kristensen and Hain and incubated for 24 hours at 37°C. In this paper has been performed a statistical analysis. Statistical analysis is an indispensable tool for interpreting and drawing meaningful conclusions from experimental data. It helps in identifying significant differences between samples, establishing correlations between variables, and predicting the behaviour of bacteria presence under different conditions. It is more appropriate to use Spearman correlation, which measures the strength and direction of association between two ranked variables. In order to detect the relation of various variables associated to each other we perform a correlation analysis using the Spearman correlation matrix. The correlation is performed using symbolic programming language MATLAB R2024b.

RESULTS AND DISCUSSION

Table 2 and figure 4 present the microbiological parameters of the water of the 10 analyzed wells. It is observed that wells 5, 6 and 9 are clean in terms of microbial parameters.

Table 2. Results of microbiological analyzes for well waters

	Autumn 2023		Winter 2023		Spring 2024		Summer 2024	
	E. coli	*Intestinal enterococci*	*E. coli*	*Intestinal enterococci*	*E. coli*	*Intestinal enterococci*	*E. coli*	*Intestinal enterococci*
well water 1	9	201	1	49	3	158	7	192
well water 2	12	196	2	53	5	144	9	165
well water 3	7	198	0	16	0	122	5	184
well water 4	43	101	5	13	18	76	24	88
well water 5	0	0	0	0	0	0	0	0
well water 6	0	0	0	0	0	0	0	0
well water 7	5	19	0	1	1	3	3	9
well water 8	8	206	0	60	0	148	4	154
well water 9	0	0	0	0	0	0	0	0
well water10	90	45	22	6	52	14	68	22



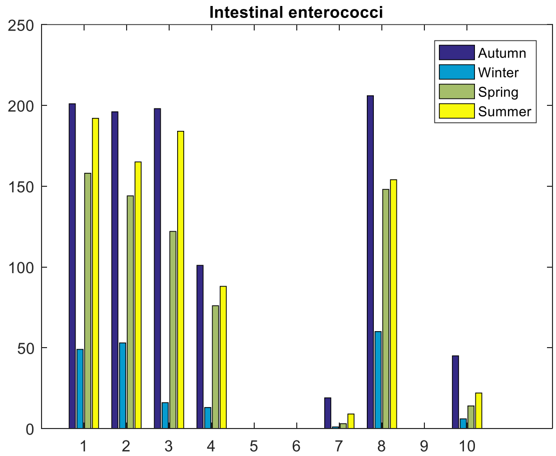


Figure 4. The dynamics of the spread of microbiological analyzes for well waters

The wells built near the lake of Shkodra in the area of Shiroka, it is observed that they have a pollution above the norms allowed for the use of this water according to Directive 98/83EC. We must add that the owners also use this water for small businesses such as restaurants or cafes. In these two wells, *Intestinal enterococci* dominates endangering people's health. There are septic tanks near these two wells, and during the rainy season they contaminate the water of the wells. From an engineering point of view, there is often no maximum safety in their construction. Likewise, in table 2 and in figures 5 and 6, the wells at the entrance to Buna and the Viluni area on the Adriatic side are very contaminated. It is worth noting that along the Buna river we have pollution of wells, with the exception of well 6 in the area of Darragjat, this is due to the composition of clay, which serves as a filter, preventing the penetration of pollution.

Seasonal monitoring data for the years 2023-2024 show that water samples from well 1 result outside the permitted limits according to the drinking water quality directive for microbial loads with *E. coli* and *Intestinal enterococci.* The highest levels of contamination were recorded in the autumn season of 2023, where for *E. coli* it resulted in 9 CFU/100 ml and for *Intestinal enterococci* 201 CFU/100 ml, constituting a risk to public health. After the fall, higher concentrations were identified in the summer of 2024 with 7 CFU/100 ml for *E. coli* and 192 CFU/100 ml for *Intestinal enterococci*, followed by the spring of the same year with 3 CFU/100 ml *E. coli* and 158 CFU/100 ml *Intestinal enterococci*, the results again remaining outside the permitted limits, making the water unfit for consumption throughout the monitoring period.

Results of well 2: the highest values were recorded in autumn 2023 with 12 CFU/100 ml for *E. coli* and 196 CFU/100 ml for *Intestinal enterococci*, signalling significant pollution in this period. In the following season, summer 2024, a slight decrease in both parameters was observed 9 CFU/100 ml *E. coli* and 165 CFU/100 ml *Intestinal enterococci*. The decreasing trend gradually continued in spring 2024 with 5 cfu/100 ml of *E. coli* and 144 cfu/100 ml *Intestinal enterococci*, the lowest values were recorded in winter 2023 with 2 cfu/100 ml of *E. coli* and 52 cfu/100 ml of *Intestinal enterococci.*

Data obtained from well 3 regarding *E. coli* resulted in 0 cfu/100 ml in winter 2023 and spring 2024, indicating an improvement in water quality for this parameter. However, contamination with *E. coli* in the warmer seasons was present; specifically, in autumn 2023, maximum values of 7 cfu/100 ml were recorded, while in summer 2024, maximum values of 5 cfu/100 ml were recorded. For *Intestinal enterococci*, a high load was observed in all periods, where the peak of contamination was in autumn 2023 with 198 cfu/100 ml followed by summer 2024 with 184 cfu/100 ml, spring 122 cfu/100 ml and winter with a decrease of 16 cfu/100 ml. Finally, well 3 sometimes presents an absence of *E. coli,* the continuous presence of intestinal enterococci indicates that the water is microbiologically unsafe for consumption in all periods of the season analysed.

In well 4, the highest value recorded for *E. coli* was in autumn 2023 with 43 cfu/100 ml. During the following seasons, a gradual decrease in the microbial load was observed, with 24 cfu/100 ml in summer, 18 cfu/100 ml in spring and 5 cfu/100 ml in winter 2023. For *Intestinal enterococci*, autumn had the highest concentration of 101 cfu/100 ml, followed by summer with 88 cfu/100 ml, spring with 76 cfu/100 ml and finally winter with 13 cfu/100 ml.

In contrast to other wells where the norms for drinking water are exceeded, in well 5, well 6 and well 9, the results showed that they are within the norms of Directive 98/83/EC for drinking water. In all the seasons monitored in these three wells no pathogenic colonies of *E. coli* or *Intestinal enterococci* were found, resulting in 0 cfu/100 ml. These wells within the norms can be linked to several factors, such as the structure of the wells within the standards, the hygienic and sanitary conditions around them, and the lack of septic tanks near the well. Therefore, these wells can be considered a model in terms of their management and maintenance.

Well 7 has a more limited microbial decrease compared to other sources. During the fall of 2023 we have 5 cfu/100 ml for *E. coli* and 19 cfu/100 ml of *Intestinal enterococci*. In the summer of 2024 a significant decrease was observed in both parameters with 3 cfu/100 ml of *E. coli* and 9 cfu/100 ml of *Intestinal enterococci*. The further decrease continued in the spring, where *E. coli* resulted in 1 cfu/100 ml and *Intestinal enterococci* i in 3 cfu/100 ml. In the winter of 2023 microbial contamination was minimal with *E. coli* at 0 cfu/100 ml but with *Intestinal enterococci* with 1 cfu/100 ml. Despite the low load, their presence in the indicators shows that the well water does not meet the conditions, so it is not considered safe to drink.

In well 8 we have a significant presence of pollution in the autumn and summer months. In autumn 2023, we have 8 cfu/100 ml for *E. coli* and 206 cfu/100 ml for *Intestinal enterococci*. In summer 2024, we have 4 cfu/100 ml for *E. coli* and 154 cfu/100 ml for *Intestinal enterococci*. In colder periods a gradual disappearance of *E. coli* is observed, where we have 0 cfu/100 ml in winter and spring, but we have the presence of *Intestinal enterococci* with 148 cfu/100 ml in spring and 60 cfu/100 ml in winter.

The data from well 10 shows a higher prevalence of *E. coli* compared to *Intestinal enterococci* in all monitored seasons. In autumn 2023, the concentration of *E. coli* has higher values with 90 cfu/100 ml, while *Intestinal enterococci* have 45 cfu/100 ml. This trend continues in summer 2024 with 69 cfu/100 ml and 22 cfu/100 ml *Intestinal enterococci* A gradual decrease in both parameters is observed during spring 52 cfu/100 ml for *E. coli* and 14 cfu/100 ml for *Intestinal enterococci*. In winter 2023 the load drops with E. coli 22 cfu/ 100 ml and 6 cfu/100 ml for *Intestinal enterococci*

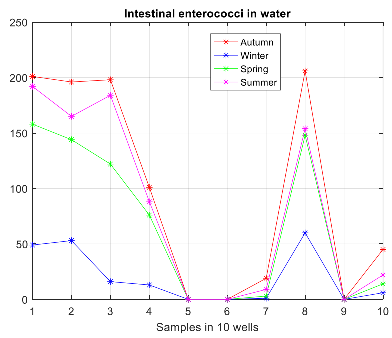


Figure 5. Seasonal distribution of *Intestinal enterococci* in the 10 wells

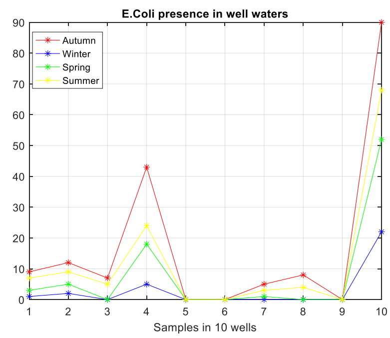


Figure 6. Seasonal distribution of *E. coli* in 10 wells

Table 3. Results of pathogenic bacteria causing waterborne diseases

	Escherichia coli	*Shigella flexneri*	*Salmonella typhimurium*
Autum 2023	142	2	15
Winter 2023	112	7	12
Spring 2024	126	0	8
Summer 2024	117	0	11

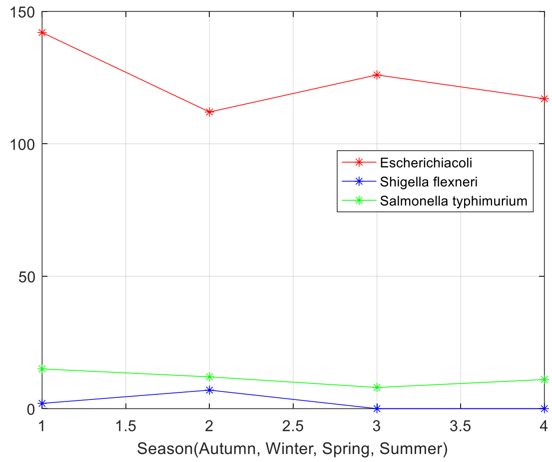


Figure 7. Dynamics of pathogenic bacteria causing waterborne diseases

Table 3 and Figure 7 show that, from the results and the dynamics of the spread of water-borne diseases, the cases caused by *E. coli* (mainly diarrhoea) dominate, compared to shigellosis and salmonellosis. Specifically, *E. coli* results in 90.36% of all positive cases of these diseases. *E. coli* was present in a very significant number of cases for enteric pathogens, appearing as a main indicator of contamination. In cases where others were identified, *Salmonella typhimurium* was found to be the most frequent after *E. coli*, while *Shigella flexneri* was found in lower concentrations and with much rarer frequency. These results indicate the transmission of gastrointestinal infections as a result of water contamination.

Table 4. Results of bacteria in well water and bacteria causing water source diseases according to seasons

	Intestinal enterococci (in Water)	*Escherichia coli (in Water)*	*Escherichia coli* (disease)	*Salmonella typhimurium* (disease)	*Shigella flexneri* (disease)
Autum 2023	966	174	142	15	2
Winter 2023	198	30	112	12	7
Spring 2024	665	79	126	8	0
Summer 2024	814	120	117	11	0

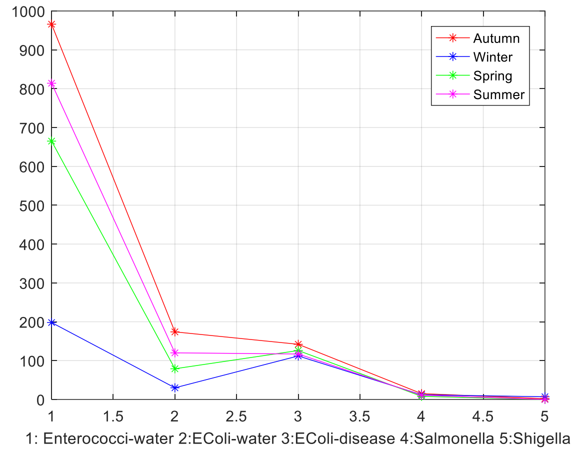


Figure 8. The dynamics of bacteria presence and disease in different seasons

In the above graph we have presented the values of enterobacteria incidence in well water and three diseases throughout the four seasons. From the result of the measurement, we conclude that we encounter higher values of bacteria presence respectively during the Autumn and Summer, which are the driest seasons. As regard to the incidence of the diseases considered we conclude that they do not differ much with respect to the various seasons.

In order to perform a correlation analysis at first, we will perform some descriptive analysis and we have presented a boxplot and the normal distribution test to choose the most robust correlation.

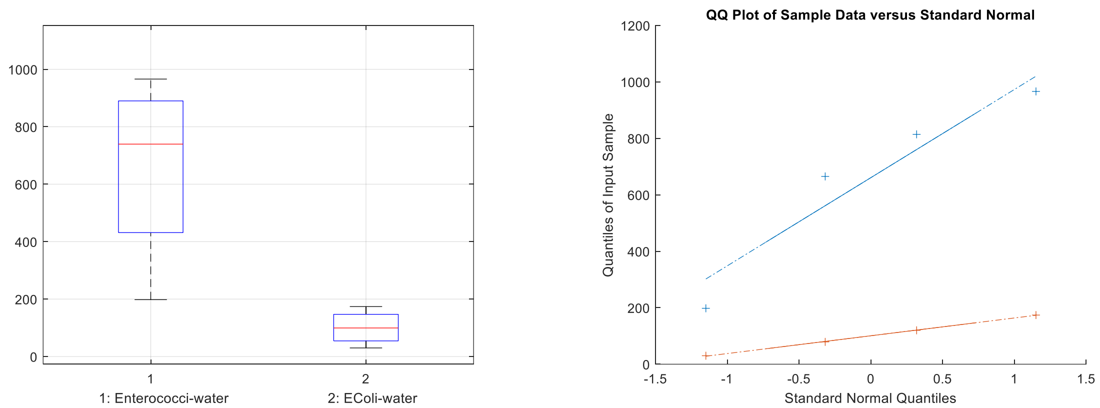


Figure 9. Left: Boxplot graph for bacteria in well water; Right: QQplot for bacteria in well water

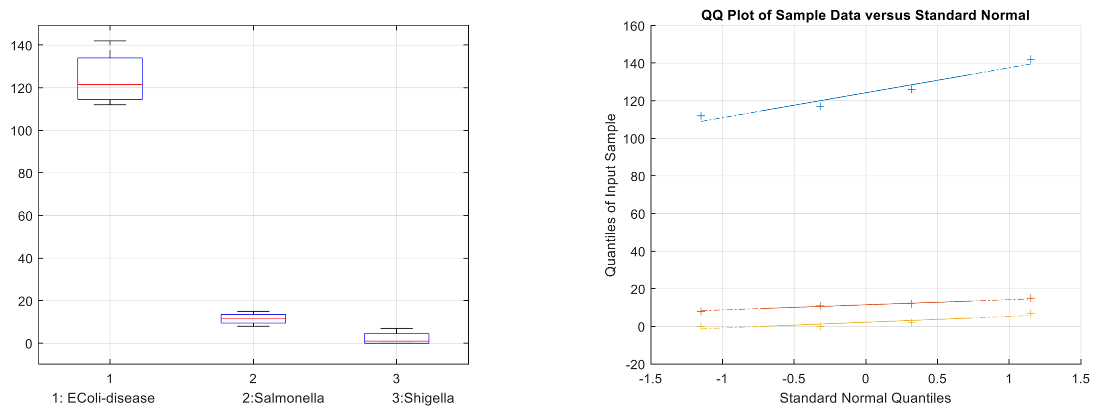


Figure 10. Left: Boxplot graph for diseases; Right: QQplot for diseases

From the above graphs we conclude that for the data of *Escherichia Coli (disease)* we see the presence of non-normality. According to our conditions with a small size and the presence of non-normal data we conclude that it is more appropriate to use Spearman correlation, which measures the strength and direction of association between two ranked variables, calculated with the following formulae

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \quad \ldots (1)$$

where n – number of observations, d_i -difference between the two ranks of each observation.

In order to detect the relation of various variables associated to each other we perform a correlation analysis using the Spearman correlation matrix, presented in heatmap Figure 11. The correlation coefficients range from -1 to 1. The closer to 1 or -1, the stronger the relationship between the two variables. Negative values indicate a negative correlation, and positive values indicate a positive correlation. Values close to 0 indicate no correlation between variables.

To understand whether the presence of bacteria affects the incidence of three specific disease-causing bacteria, correlation analysis was performed. Spearman's correlation coefficients were calculated to correlate the presence of the two types of bacteria in drinking water, *E. coli* and *Intestinal enterococci* with the three pathogenic bacteria, *Escherichia Coli (disease), Salmonella* and *Sh. flexneri* causing disease in humans. Figure 11 after performing a cross-correlation for the presence of bacteria in water with respect to disease incidence, it was distinguishable that the presence of *Intestinal enterococci* drinkable water correlates positively with the incidence of *Escherichia Coli (disease)* and the presence of *Escherichia Coli in water* correlates positively with the incidence of *Escherichia Coli (disease).*

Table 5. Table of Spearman correlation of bacteria and disease variables.

	Intestinal enterococci (in water)	*Escherichia coli (in water)*	*Escherichia coli (disease)*	*Salmonella typhimurium*	*Shigella flexneri*
Intestinal enterococci (water)	1	1	0.8	0.4	-0.31623
Escherichia coli (water)	1	1	0.8	0.4	-0.31623
Escherichia coli (disease)	0.8	0.8	1	0.2	-0.31623
Salmonella typhimurium	0.4	0.4	0.2	1	0.737865
Shigella flexneri	-0.31623	-0.31623	-0.31623	0.737865	1

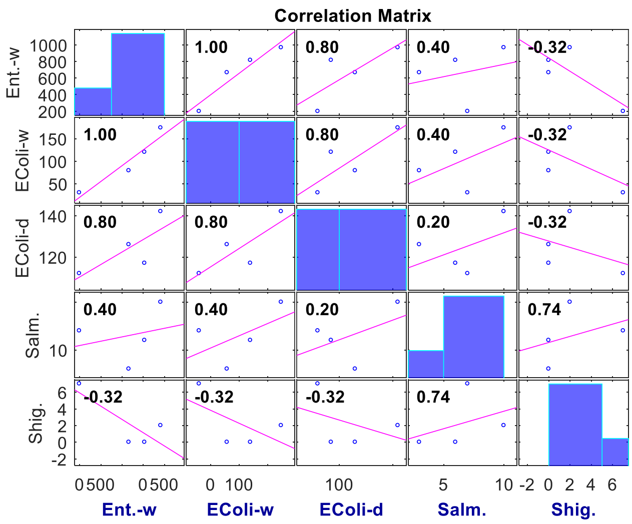


Figure 11. Spearman correlation matrix of the presence of bacteria in water with respect to disease incidence.

From the correlation analysis we conclude that the presence of *Intestinal enterococci* in well water correlates 100% with the incidence with *Escherichia coli* in well water and 80% with the incidence of the *Escherichia coli (water)*. The second evidence is that *Escherichia coli disease* correlates 80% with the presence of *Intestinal enterococci* in well water and 80% presence of *Escherichia coli disease*. The third conclusion is that *Salmonella typhimurium* correlates 74% with *Shigella flexneri*. The correlation is performed using symbolic programming language MATLAB R2024b.

We conclude that the concentration of *Intestinal enterococci* in the water of wells in the region of Shkodra is significantly above the allowed rates. Also, the presence of *E. coli* in 7 out of 10 wells indicates a fecal pollution with an impact on the family environment based on many activities in the use of this water. Various factors contribute to the deterioration of water quality, which affects the wells near the Shkodra lake, those of the Viluni lagoon, and good quality in the Adriatic Sea area. There are no septic tanks in this well area, thanks to the creation of the sewage plant. From the analysis, this study revealed that the socio-demographic, economic, industrial, etc., characteristics are related to the contamination with *E. coli* and *Intestinal enterococci*. Compared to previous studies such as those conducted by the author Gbèssohèlè Justin Behanzin et al (2024) that reported higher levels of *Intestinal enterococci* the results of our study also showed higher concentrations relative to *E. coli.* This consistent trend across studies indicates a link to the dominance of intestinal enterococci as a control of faecal contamination.

As a result, the water from wells 5, 6 and 9 is within the standards and can be consumed. While the other wells do not meet the standards for drinking and should not be consumed or used in other services without prior treatment or without being filtered. The contamination of these wells by pathogenic faecal bacteria poses a great risk to public health and the various consumers who use them. The situation presented in this paper should also be made available to the responsible local authorities to control the problematic areas by improving the service in them.

This study brings a new scientific contribution since, for the first time in the Shkodra area, in several areas with different habitats, the analysis of water from private wells was carried out to assess the relationship between microbial water pollution and related diseases. One of the limitations of this study is the non-inclusion of physical and chemical parameters, or metals in the water, since we are dealing with different habitats. The construction of wells was also taken into consideration.

The study represents a unique and original contribution since to date no similar microbiological studies have been carried out on the quality of groundwater in the studied areas. Furthermore, the presence of pathogens in well waters intended as drinking water has been highlighted for the first time, highlighting the correlation they have with the disease-causing bacteria that generate them with a direct impact on public health. In the study area, there is a lack of documented data on the presence of *Intestinal enterococci* and *E. coli* in the waters of the wells taken in the study.

For this reason, the results were compared with similar studies carried out in other European countries such as: Finland, Italy, Romania and Ireland in order to contextually evaluate the data and identify common factors or identify common or distinctive factors that affect their microbiological quality. The factors identified by the study results as important in this study are in line with those reported and found in the literature, which provide an overview of the factors that influence contamination. The results of the study are in line with those reported by Tarja Pitkänen et al (2010) in the country of Finland, where it was observed that 25% of the analysed wells were contaminated with *E. coli* and *Intestinal enterococci*. The authors of this study linked the contamination mainly to technical factors, namely the structure of the constructed wells and the environment in which the bacteria spread. In our study the percentage of contaminated wells was high, which indicates that contamination remains an important concern, especially in the absence of well construction standards.

The results of our study are also consistent with those of Osvalda et al (2016) in the Apulia region, Italy, where it was found that the level of microbial contamination in wells exceeded the limits allowed by European directives and that this contamination varies depending on the seasons and the hydrogeological characteristics of the aquifer. The authors emphasise that aquifers with karst and fractured composition are more vulnerable to the spread of microorganisms due to the rapid flow of water and the reduction of the filtration capacity, while sandy or gravelly aquifers offer higher natural filtration capacity, limiting the movement of pathogens. The study in the Shkodra area supports this assumption specifically the water of well 5 (Berdica area), located in an area with gravel composition, as well as the water of well 6 (Darragjat) in a rocky area and the water of well 9 near the coastline in a sandy area results in clean water within the permitted norms for consumption regarding the presence of *E. coli* and *Intestinal enterococci*. (Aliaj, S et al 2001). This suggests that the type of aquifer has an important role, in addition to the norms of well construction, in the natural protection of groundwater from microbiological pollution.

The study by Zamfira Stupar et al. (2022) in Romania evidenced high levels of microbiological contamination from six sources analysed, five of which were contaminated, posing a considerable risk to public health, especially for groups such as children who are more susceptible to gastrointestinal infections. In line with these findings, this study also identified contamination of wells and the spread of diseases as a result of drinking contaminated, undisinfected water.

One of the limitations of this study is the focus only on some specific microbiological parameters, namely Escherichia coli and intestinal enterococci. Other parameters such as total coliforms, Clostridium perfringens and others that serve as indicators of pollution and that are related to the occurrence of infectious diseases are not included. In addition to bacteria, well water can also contain parasites and viruses that are present in human sewage and animal waste. Therefore, future studies in the accurate detection of microbial contaminants should use molecular methods in their more detailed identification. This remains a recommendation for new, more in-depth studies.

Recommendations: Wells should be checked for the way they are built, since in most cases they are not built according to the standards that require wells used for drinking water to have a use permit. For this reason, we recommend their certification, otherwise they should not be used, and residents should be supplied with water sources approved and certified by the competent authorities. Unsafe sources should be continuously monitored until their rehabilitation, otherwise their closure and non-use should be required. Also, well water should be systematically controlled, even more often than planned, for its disinfection method. Also, chlorination should be controlled and kept within the allowed norms. We recommend that better investments be made in research and care in the sanitation of waters with an impact on public health, accompanied by community education about the risk posed by unsafe water. We also recommend the use of water filters. Filtration technology and disinfection systems such as chlorination or the use of ultraviolet rays are essential components for improving water. It is recommended that relevant institutions work closely with residents to guarantee the quality of well water and take concrete steps to prevent contamination and the spread of diseases.

CONCLUSION

To ensure uncompromising health, we also recommend improving the water quality of the wells, which is ensured by their periodic monitoring. This monitoring should be carried out with high priority by the local authorities that are responsible for ensuring the safe consumption of drinking water. Likewise, the coordination in the construction and management of a number of actors, such as local institutions, residents, public health workers, education of residents, etc. The cooperation between these groups is important for the improvement of the infrastructure; also, they are encouraged to report any problem related to the water quality in the area around them.

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AUTHOR CONTRIBUTIONS

O L, K P conceptualization and methodology; O L collecting samples and performing laboratory analyses; E K processing and statistical analysis of data.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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