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ASSESSMENT OF PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF WELL WATER USED FOR DRINKING AND DOMESTIC PURPOSES IN AN INDUSTRIAL AREA OF ELBASAN DISTRICT, ALBANIA

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Abstract

Rapid population growth, urbanization, and unsustainable water management practices have all contributed to the depletion of freshwater resources. Groundwater is considered an important source for drinking and domestic purposes. In most cases, groundwater is threatened by physical, chemical, and microbiological contamination. The sources of groundwater contamination are numerous and have severe implications for public health. This study aims to assess the physicochemical and bacteriological quality of well water used for drinking and domestic purposes in the industrial area of the Elbasan district. Samples were collected from 57 wells and analysed for bacteriological (Total Coliforms and Escherichia coli) and physicochemical quality (pH, Electrical conductivity, total phosphorus, sulfate, ammonia, etc.) using standard methods. The collected data were subject to statistical analysis using the SPSS software ver. 22. Physicochemical results revealed that 65% of wells did not meet WHO standards and Albanian guidelines set for drinking water. In terms of bacteriological analysis, 80% of the samples were contaminated with total coliforms and 19% with E. coli. Based on analysis of heavy metals some samples exceeded the limits of iron and lead content.

Key words*: bacteriological quality, groundwater, physicochemical quality, well water.*

INTRODUCTION

Groundwater is a significant water supply source, which constitute about 20% of the world's supply (Jyothilekshmi et al., 2019). It is considered an essential source of human development, for a range of different sectors, and environmental flows (Velis et al., 2017).

Recently, scientists and decision-makers have been paying more attention to sustainable water resource development and management due to limited water resources and rapid socioeconomic development (Tang et al., 2021). Freshwater has vital importance, and for many years its availability in urban areas has been a priority objective of the world (WWAP, 2019); therefore strategic importance for global water and food security is being intensified under climate change as more frequent and intense climate extremes increase precipitation, soil moisture, and surface water availability variability (Vadiati et al., 2018)

Due to increasing population growth, human water demand for drinking, domestic, industrial, and agricultural purposes increases as well (UNDP, 2006), and water is becoming a scarce commodity in most of the world. On the other hand, an increase in population affects the quantity and quality of water, and any physical or chemical pollution causes changes to the quality of the receiving water body (Aremu et al., 2011).

Groundwater is an indispensable resource for our planet, considered the most preferred source of drinking water worldwide, more reliable than surface water, and more accessible (Naomi et al., 2019; Marggat, 2013). According to Jakeman et al. (2016), groundwater provides over 97% of accessible freshwater, half of the drinking water, and approximately half of the irrigation water for agriculture.

Wells are one of the major sources of groundwater and have long been considered one of the purest forms of water in nature and meet the overall demand of rural and semi-urban residents (Nair et al., 2013).

As mentioned in the work of Devolli et al. (2017), approximately 70 % of Albanian cities use groundwater to fulfil their needs. Furthermore, the wells in the Elbasan district provide a reliable and ample water supply for drinking, domestic, and agricultural irrigation purposes (Osmani et al., 2023). However, water is a critical component of public health and failure to supply safe water places a heavy burden on humanity, industrial pollution (toxic elements), agricultural residues (runoff fertilizers), and microbial contamination are major concerns of groundwater sources which can affect the water quality and consequently human health (Yasin et al., 2015). These contaminants are further categorized as microorganisms, inorganics, organics, radionuclides, and disinfectants (Nollet, 2000).

Albanian public water system uses water treatment and monitoring to protect consumers from such contaminants, but generally, the water quality of private wells is not covered by Albanian legislation and regulations of drinking water quality monitoring. Well-owners are responsible for protecting and monitoring water quality and must be aware of the potential of well-water contamination and the possible health effects (Osmani et al., 2023; Devolli et al., 2017).

Although private well-owners, unlike public water supplies, are legally obliged to test their water quality frequently (Schuitema 2020), however in practice, they rarely follow these recommendations and mostly test their well water only if problems arise (Hooks et al., 2019; Devolli et al., 2017).

As a result, the water quality of private wells is a major concern and there is an inevitable need for regular water testing and monitoring.

Recently, the implementation of instrumentation such as GPRS (General Packet Radio Service) destined for water quality evaluation (testing and monitoring of chemical parameters) allows using a mobile device to view results and receive text warnings via SMS about the quality of groundwater and potable water in a real-time (Ionel et al., 2015).

The current study aims to assess private well water quality used to fulfil the drinking, domestic, and irrigation needs of the rural community in an industrial area of Elbasan district. Analyzing physicochemical parameters, heavy metal content, and bacteriological quality of well water was the main objective of this study. WHO guidelines and Albanian standards were used to assess the overall well water quality for drinking and household purposes.

MATERIALS AND METHODS

Description of Study Area

The study was conducted in 2022 at Bradashesh village, located in the industrial area of Elbasan district. Geographically, the study area is situated 4 km from Elbasan city between 41°06'09.3"N and 20°01'29.4"E (Figure 1).

This City suffers from problems related to overpopulation, such as waste management, high levels of air pollution, and significant noise pollution (Lazo et al., 2021).

According to the data of INSTAT 2022, the economy of this community is predominantly based on livestock farming and heavy industry (metallurgic plant and metal processing factory). The metallurgical complex considered as the biggest industry in the country is situated in the vicinity of the Bradashesh village (Shtiza et al., 2009).

Sample collection

About 75% of the total rural community is dependent only on their private well water to fulfil domestic consumption and drinking needs (Devolli et al., 2017; Osmani et al., 2023). A total of 57 well-water samples from 7 representative selected stations within the study area (Figure 1) were collected. Water wells ranged from 35 to 50 meters deep. Samples collection and treatment were carried out in accordance with the standard methods ISO 5667-5:2006; APHA, 2017; WHO, 2017.

Water samples should be representative of well water quality. Initially, the water was allowed to run at full flow from the pump for 10 minutes to ensure that the water sample represented the quality of groundwater that feeds the deep well before sampling.

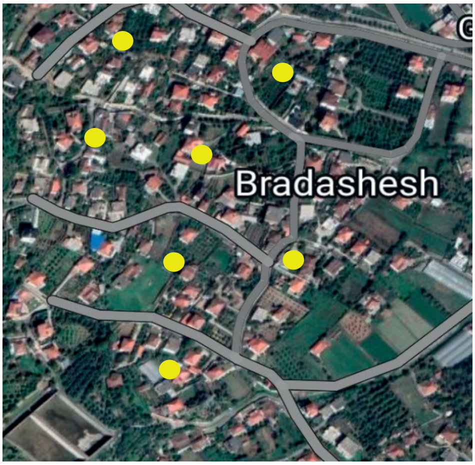

Figure 1. Map of the study area (yellow circles specify sampling stations) (Source: Google Maps)

The samples were collected in 1-liter polyethylene (PET) bottles and were immediately transported to the laboratory in a thermo-box to avoid any contamination. There were used 250 mL sterile plastic bottles for microbiological analysis.

Physicochemical analysis

The collected water samples were analysed for various physicochemical parameters such as temperature, pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity (TA), total hardness (TH), calcium, magnesium, chloride, sulphate, phosphate, ammonium, nitrite, and nitrate according to the standard analytical methods for the examination of water and wastewater (APHA, 2017).

Temperature, pH, electric conductivity (EC), and total dissolved solids (TDS) were determined in situ using a multi-parameter water analyser WTW 3620 IDS. The measurement of TSS in water samples was carried out according to the standard APHA (2017) method by the filtration process.

The total alkalinity was determined using titrimetric method. Total hardness, calcium and magnesium hardness were determined using EDTA titrimetric method. Chloride concentration was determined using argentometric titration method (AWWA, 2011). BOD content in well water samples was determined by the Winkler method as described by APHA (2017), while the COD concentration was determined according to the standard method 5220D with an accuracy of 0.1 mg COD per litre (APHA, 2012).

The anions sulphate, phosphate, ammonium, nitrite and nitrate were determined by using a WTW Spectrophotometer 7100 VIS.

Acidified well water samples (pH = 2) were analysed for the presence of heavy metals (lead, zinc, copper, iron and cadmium) by using a Flame Atomic Absorption Spectrometer (Analytik Jena GmbH - novAA 400 P).

All chemicals and reagents were of the analytical grade, and doubly distilled water was used for dilutions.

Bacteriological analysis

Microbiological load (Total Coliforms and *Escherichia coli*) in well-water was carried out through the membrane filtration method (ISO 9308-1:2014).

The plate count was conducted by pouring the plate technique on Plate Count Agar (PCA) and counting the colonies developed after the incubation. Enumeration of colonies was done as described by Rodier et al., (2009) and results were expressed as colony forming units (CFU)/100ml. M-Endo Agar LES medium was used for enumeration of *Escherichia coli* in water using a two-step membrane filter method. Inoculation temperature was 44˚C for 24 hours. Violet Red Bile Agar medium was used for the detection of Total Coliforms at an incubation temperature of 37˚C for 48 hours.

Statistical analysis

Analyses of water samples were conducted with 3 replications. The collected data were subject to statistical analysis and analysis of variance (ANOVA) at a 5% level of significance to determine the physicochemical and bacteriological quality variations among all site stations of private well-water sources using the SPSS software ver.22.

The relationships between the physicochemical parameters and bacteriological quality in the water samples were established using Pearson correlation, and also there was utilized the multivariate analysis of Cluster Analysis (CA).

RESULTS AND DISCUSSIONS

Table 1 represents analytical results of the physical parameters of private well water samples collected from seven stations (E1 to E7).

The obtained results were evaluated and compared with WHO guidelines and Albanian standards for drinking water quality (WHO 2017; STASH 1998).

The pH values of well water samples ranged from 6.98 to 8.05, within the recommended limits of WHO guidelines and national standards for drinking water quality.

Mean values of EC varied from 660 to 1182.3 (μS/cm). It was evaluated that 90% of well water samples exceeded the threshold value allowed for drinking water according to WHO guidelines and Albanian standards (400-600 μS/cm). High conductivity in water can occur due to natural sources such as minerals, or as a result of industrial activity. The lowest and highest content of electric conductivity was registered in the E1 and E2 water sample stations, respectively.

TDS content in analysed water samples ranged from 246 to 1020 mg/L. 10 % of water samples exceeded the WHO standard and 30% exceeded the maximum concentration of TDS specified in the Albanian standard (500 mg/L). Higher values of TSS and turbidity were recorded at station E4, 44 mg/L, and 7.66 NTU, respectively.

The alkalinity of well water is due to the presence of mineral salts, primarily carbonate and bicarbonate ions. It does not play a significant role in human health, but it makes water tasteful and helps in coagulation (Hussain et al., 2021). The minimum value should be 30 mg HCO_3^-/L, and the maximum permitted level should not exceed 100 mg HCO_3^-/l.

As is noticed in Figure 2, all analysed water samples exceeded the maximum permitted level according to WHO guidelines for drinking water quality.

Regarding TH, most of the well water samples exceeded the maximum level set by WHO and STASH (300 mg/L) for drinking and domestic purposes, while the samples of stations E1 and E2 resulted within the hardness standard.

Table 1. Results of physical parameters of well water samples

	pH			EC (μS/cm)		
site code	*Mean*	*SD*	*Range*	*Mean*	*SD*	*Range*
E.1	7.617	0.217	0.53	660.0	83.77	205.0
E.2	7.263	0.221	0.54	1182.3	57.41	129.0
E.3	7.610	0.297	0.71	954.0	74.55	174.0
E.4	7.950	0.082	0.20	691.0	55.36	134.0
E.5	7.597	0.097	0.23	961.7	82.04	200.0
E.6	7.600	0.147	0.35	943.7	81.08	192.0
E.7	7.687	0.152	0.34	967.3	154.6	378.0
WHO*	6.5-8.5			400.00		
site code	**TDS (mg/l)**			**TSS (mg/l)**		
E.1	352.0	76.7	179.0	9.50	2.68	6.50
E.2	772.8	77.0	188.6	17.53	1.91	4.60
E.3	679.9	129.2	313.4	8.37	1.03	2.50
E.4	437.0	50.3	123.0	44.00	6.98	17.00
E.5	757.2	207.2	506.4	6.87	0.78	1.90
E.6	552.9	52.8	125.2	8.47	1.91	4.40
E.7	710.7	154.2	356.0	12.93	3.02	7.40
WHO*	500-1000			25		
site code	**Turbidity (NTU)**			**Temperature (^{0}C)**		
E.1	0.70	0.14	0.33	16.17	0.74	1.70
E.2	1.08	0.45	1.09	15.83	0.45	1.10
E.3	0.96	0.21	0.49	15.03	0.31	0.70
E.4	7.66	0.70	1.71	15.03	0.40	0.90
E.5	1.94	0.21	0.48	16.07	0.31	0.70
E.6	0.76	0.15	0.35	15.57	0.17	0.40
E.7	2.12	0.56	1.33	15.57	0.77	1.80
WHO*	5			25		

WHO* - World Health Organization 2017 Guidelines for Drinking Water Quality (2017).

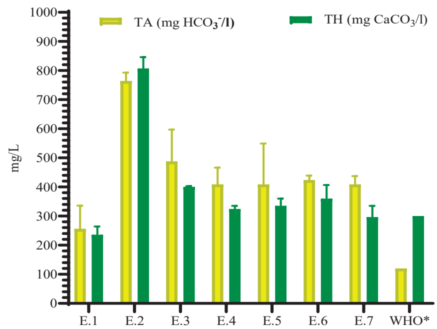

Figure 2. Variation of Total Alkalinity (TA) and Total Hardness (TH) of well water samples in 7 stations compared with WHO guidelines

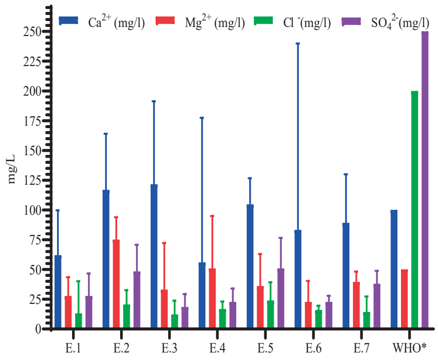

Figure 3. Variation of ions Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} of well water samples in 7 stations compared with WHO guidelines

Principally, the Ca and Mg presence is responsible for the hardness of the water, and their permitted limits are 100 mg/L and 50 mg/L, respectively (WHO, 2017). The high amount of magnesium imparts a repulsive taste to drinking water (Worako, 2015).

In the current study, the concentration of magnesium in all the analysed water samples was within WHO guidelines (Figure 3). The chloride and sulphate concentrations were below the WHO guidelines, 200 mg/L and 250 mg/L, respectively.

In the case of sampling stations (E2, E3, and E6), the concentration of Ca^{2+} exceeded the allowed limitation set by WHO guidelines for drinking water quality (Figure 3).

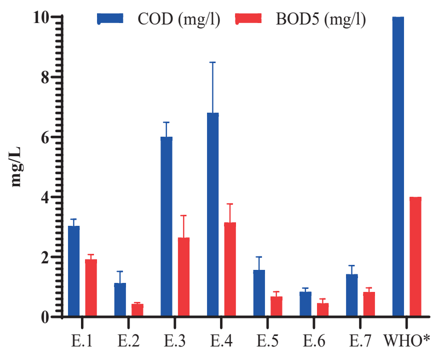

Figure 4. Variation of COD and BOD of well water samples in 7 stations compared with WHO guidelines

BOD is an indicator of the organic pollution of water, while the COD indicates the organic matter present in a water sample (Clair, 2003).

As shown in Figure 4, the content of BOD and COD in all analysed water samples was beyond the permissible limits of WHO guidelines 4 mg/l and 10 mg/L, respectively.

As noted in Table 2, the concentrations of nitrites, nitrates, ammonia, and phosphates in all analysed water samples were within the WHO guidelines and Albanian standards recommended for drinking water quality.

Table 2. Results of chemical parameters of well water samples

	PO_4^{3-} (mg/L)			NO_3^- (mg/l)		
Site code	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
E.1	0.102	0.077	0.19	1.373	0.928	2.27
E.2	0.460	0.207	0.47	12.187	5.185	12.70
E.3	0.727	0.214	0.52	1.864	0.980	2.11
E.4	0.330	0.164	0.40	3.109	1.480	3.22
E.5	0.830	0.234	0.52	5.767	2.027	4.85
E.6	0.490	0.219	0.47	12.20	3.048	7.42
E.7	0.523	0.296	0.66	8.383	1.579	3.85
WHO*	2.00			50.00		
Site code	**NO_2^-(mg/L)**			**N-NH_4**		
E.1	0.005	0.003	0.01	0.045	0.012	0.03
E.2	0.000	0.000	0.00	0.483	0.143	0.35
E.3	0.002	0.000	0.00	0.061	0.021	0.05
E.4	0.031	0.022	0.05	0.136	0.030	0.07
E.5	0.007	0.001	0.00	0.189	0.077	0.18
E.6	0.018	0.004	0.01	0.033	0.012	0.03
E.7	0.007	0.002	0.00	0.147	0.064	0.16
WHO*	0.1000			0.5000		

The presence of heavy metals in drinking water higher than a certain concentration can have detrimental impacts on human health (Shehu, 2022).

Water quality assessment concerning heavy metals was based on the safe limits set by WHO and Albanian legislation. In the present study, the mean values of heavy metals (Fe, Cu, Zn, Cd, Pb) analysed in well water samples are presented in Table 3. In the case of stations (E3, E4, E6, and E7), the values of Cd concentration exceeded the allowed limitation of 0.005 ppm.

The concentration of lead in stations E3, E4, and E6 exceeded safe limits due to nearby industrial activity in the study area.

Table 3. Concentration of heavy metals (mg/L) in well water samples

Site code	Fe (m/L)	Cu (mg/L)	Cd (mg/L)	Pb (mg/L)	Zn (mg/L)
E.1	0.0502	1.0078	0.0067	0.00629	0.3072
E.2	**1.0263**	**2.067**	0.0032	0.0281	0.7601
E.3	0.0802	1.1064	**0.0458**	**0.8405**	0.4025
E.4	**2.0675**	**3.7862**	**0.0764**	**1.0561**	1.8602
E.5	0.0903	0.9247	0.0027	0.0421	0.5162
E.6	**0.1501**	**1.0628**	**0.0163**	**0.1283**	0.6407
E.7	**0.5604**	0.0965	**0.0241**	0.0367	0.5405
WHO*	0.1	1.000	0.005	0.05	5.000

Iron is present in significant amounts in soils, principally in insoluble forms, and therefore may be present in groundwater by causing harmful effects on human health (EPA 2001). Four sampling stations (E2, E4, E6, and E7) of well water showed higher iron content exceeding the maximum level of WHO standards for drinking water quality.
A higher content of Cu was also observed in sampling stations (E2, E4, and E6). Various studies have raised concerns about the impact of high levels of air pollution and significant river water pollution in the Elbasan district due to industrial activity (metallurgical plant and metal processing factory) and the discharge of industrial waste without being pre-treated (Bekteshi, 2023). This includes heavy metal levels such as Fe, Cu, Pb, Zn, etc.

Table 4. Results of bacteriological analyses

Site code	Total coliforms (cfu/100 mL)	Escherichia coli (cfu/100 mL)
E.1	<100	0.00
E.2	<100	3.00
E.3	50-100	0.00
E.4	50-100	0.00
E.5	>10	0.00
E.6	>10	3.00
E.7	50-100	2.00
WHO*	0.00	0.00

Table 4 presents the results of microbiological analyses of well water samples collected from seven sampling stations for the presence of Total Coliforms and *Escherichia coli*. Results are expressed in cfu/100ml. Most of the analysed water samples show the presence of coliform bacteria in high concentrations. *E. coli* was detected in three sampling stations (E2, E6, and E7).

The presence of coliform bacteria in drinking water is a potential health hazard. Numerous diseases can be caused by water pollution with pathogenic bacteria, such as diarrhea and gastrointestinal illnesses (Pandey, 2014).
The evaluated microbiological indicators were found to be well above the permissible limits of WHO and STASH (zero/100 mL) for the drinking, household, irrigation, and recreational uses.
In terms of bacteriological analysis, 80 % of well water samples were contaminated with total coliforms and 19 % with *E. coli* (Figure 5).

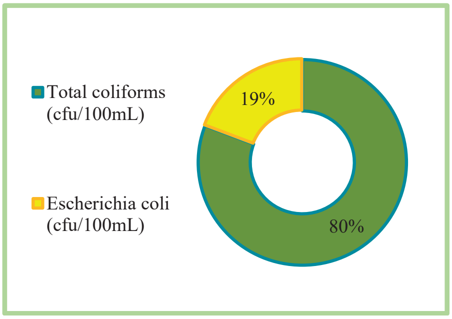

Figure 5. Percentage of Total Coliforms and *E. coli* presence in all analyzed wells

Our study points to possible fecal or surface runoff contamination of the well water sources in all sampling stations of Bradashesh village, as indicated by microbiological indicators (Total Coliform and *E. coli*).

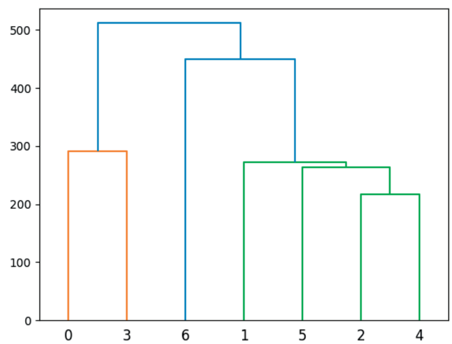

Figure 6. Dendrogram showing spatial similarities of sampling stations produced by cluster analysis

A dendrogram of the location pattern resulting from the cluster analyses (CA) is presented in Figure 6.

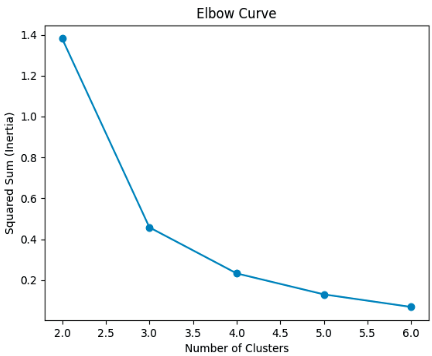

Figure 7. Elbow curve for optimal cluster number

The dendrogram shows that all the monitoring stations may be grouped into three main clusters. Cluster I is formed by stations (E1 and E4), Cluster II is formed by stations (E2, E3, E5, and E6) and Cluster III is formed by station E7. The Elbow curve also shows that the optimal number of clusters was three (Figure 7).

CONCLUSIONS

Based on the bacteriological analysis and referred to the standards set by WHO and STASH, well water quality characteristics of all collected samples from different stations of Bradashes village in Elbasan district were considered unsuitable for drinking/domestic uses without treatment.

Most of the physical data indicated marginally tolerable quality to pH, TDS, TSS, turbidity, and temperature but poor quality concerning conductivity, with values higher than permissible standards.

From the obtained results, nitrites, nitrates, ammonia, phosphates, chlorides, sulphates, BOD, and COD concentrations of well water samples were found to be within the maximum permitted level of WHO for drinking/household water quality.

The analysed wells were found to have moderately hard and hard water from the total hardness, total alkalinity, and calcium measure, hence undesirable for drinking and domestic uses.

The study concluded that in four of seven sampling stations, the concentrations of heavy metals (Fe, Cu, Cd, and Pb) exceeded the safe limits set by WHO and Albanian legislation.

This study employed multivariate statistical techniques to classify seven sampling stations located in the study area into groups of similar water quality characteristics. Cluster Analysis (CA) and Elbow curve showed that the optimal number of clusters was three.

Based on the results of this study, it is highly recommended that the wells' waters in this study area should be treated and continuously monitored to satisfy the Albanian standards and WHO guidelines recommended for drinking water quality. Treatment and hygienic practices should be improved to prevent or reduce contamination.

Water sources must be protected from contamination by human activity and animal wastes. Regular monitoring of water quality is needed to protect if further polluted. Water quality should be controlled to minimize acute problems of water-related diseases, which are endemic to human health.

Elbasan municipal council should ensure proper sanitation and water safety plans for these drinking and household water sources. They should encourage and obligate well owners to monitor water quality regularly and to test water quality frequently.

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