Water Quality and Safety of Potable Water Wells in Gjakova Region, Kosovo

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Abstract:

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Abstract

Introduction: At a basic level, everyone needs access to safe water in adequate quantities for drinking, cooking, personal hygiene and sanitation facilities, and it is a fundamental requirement for good health and also a human right.

Methods: The study is conducted from the University of Gjakova and performed in collaboration with drinking water authority National Institute of Public Health and other local authorities in Kosovo. Water samples were transported from 20 samples to the laboratory at a temperature of (4-5^{0}C). The analysis of chemical and microbiological parameters is performed according to international standard methods (ISO methods). Detection of heavy metals in drinking water is performed by ICP-MS according to EPA 6020 A.

Results: from 30 physical chemical parameters very high ammonium concentrations (2.6mg/l and higher) are observed in two water wells, which is a common indicator of anthropogenic impact through organic waste disposal, leaking sewage systems or animal waste pollution. This could be

confirmed for the well "Blloku i Ri Orize", where the total number of coliform bacteria of faecal origin is significantly higher than the national limit.

Similar situation could be observed for the Qifllak well, which shows the highest microbiological contamination (values >300cfu/100ml for all four analysed parameters) and a significantly higher ammonium concentration compared to the other samples (0.182mg/l compared to the median 0.013mg/l).

Conclusion: Studies of microbial contamination and sanitary risk could be improved by adhering to higher standards, including those outlined in our quality criteria.

Keywords: potable water well, water quality, drinking water, monitoring, public health

Introduction

Safe and good quality water is one of the most important human needs, whereas the quality of drinking water is one of the greatest factors affecting human health.[1]

A reliable, safe water supply plays an important role in disease prevention, especially by facilitating personal, domestic, and food hygiene. It has been reported that only around 71% of the total world population are using a safely managed drinking-water service, whereas at least 2 billion people globally are using a water source contaminated with faeces.[2]

Elsewhere in the developed world, the general interest has shifted significantly, with the demand for bottled water having undergone a consistent increase during the last decade (in particular), transforming the bottled water industry into the fastest growing segment within the global non-alcoholic beverage market[3]. This behaviour comes with significant consequences, given that the bottled water can cost on average 50-100 times more per litre than tap water , and does not guarantee a better quality than the tap water. Notwithstanding, the risk of acquiring a waterborne infection increases with the level of contamination by pathogenic microorganisms. Other agents, however, such as Salmonella typhi, Vibrio cholerae, Giardia lamblia and hepatitis A virus, are frequently transmitted via contaminated drinking-water.[3,4]

It is estimated that 80% of all diseases and over one-third of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one-tenth of each person's productive time is sacrificed to water-related diseases.

The World Health Organisation (WHO) as a United Nations (UN) specialized agency responsible to protect the international public health, produces international guidelines for the quality of drinking-water that are used as the basis for setting standards and regulations in both developing and developed countries.Yet, countries consider different environmental, cultural, social and economic factors when determining the guidelines to adopt as their own standards.[5]

A recent nationwide survey by the U.S. Environmental Protection Agency and Cornell University found that contamination of drinking water by septic tank effluents may be one of the foremost water-quality problems in the Nation.[6] It is estimated that up to 1.9 million people worldwide rely on water from "unimproved' sources or 'improved' sources that are fecal contaminated. Of the water-associated infections, diarrhea continues to be a leading child-killer globally, despite a decrease in under-five deaths by nearly 50 % between 2000 and 2013. Diarrheal infections disproportionately affect children living in Low- and Middle-Income Countries.[7]

Other drinking water contaminants are nitrate and nitrite, which are present in chemical fertilizers, domestic waste water and animal waste. They can reach potable water well through groundwater, surface water and water run-off. High levels of nitrate/nitrite in drinking water can cause methemoglobinemia or "blue baby syndrome". These substances reduce the blood's ability to carry oxygen. Infants below six months who drink water with high levels of nitrate can become seriously ill.[8]

The following conditions may also put people at higher risk of developing nitrate-induced methemoglobinemia: anaemia, cardiovascular disease, lung disease, sepsis and metabolic problems.[9]

The water quality standards are laid down in the drinking water Directive 98/83/EC, which is applied to all public and private water supplies intended for drinking, food preparation and other domestic purposes. The quality standards for chemical and bacteriological parameters, as well as the methods of analysis are described by the Administrative Instruction 16/2012, which is obligatory in Kosovo. According to these standards, water intended for human consumption must be free from organisms and from concentrations of chemical substances that may be a hazard to health. Temperature, absence of turbidity, and absence of colour and of any disagreeable taste or smell are of the utmost importance in public supplies of drinking-water.[10,11]

Private wells are normally not subject to the mentioned standards and monitoring programmes, but the government has to set rules to protect their users from health hazards. Unlike public drinking water systems, private wells are not included in regular monitoring programs regarding water quality. In general, the owners are responsible for ensuring good water quality, to protect their own health. Properly designed and constructed wells, normally are able to supply sufficient and safe water for at least a single household.[12,13,14]

The results of this study are considered an important contribution to improving the lack of information about the quality of the potable water wells in the area and identification of possible pollution sources. Communication of these results with the community will help in raising the awareness on drinking water quality issues and the necessity of periodic quality controls of potable water wells to ensure safe drinking water.

Materials and Methods

Study area

The study is conducted from the University of Gjakova and performed in collaboration with drinking water authority “National Institute of Public Health” which is the authorized institution for water quality control in Kosovo.

The Dukagjini region is the flat part of the Western region of the Republic of Kosovo. It lies in a length of 70 km and a width of 43 km. The Municipality of Gjakova is an administrative unit with a geographical position of 42.39 ° north, 20.43 ° east. The Municipality of Gjakova is supplied with water from the Lake "Radoniqi" in an area of 580 ha, at an altitude of 400-456.4 m and ranks second in Kosovo in terms of area. The main supplier of the lake is the river Deçan and the river Përrua of Ratisha.[15]

Municipality of Gjakova has a population of 115,859 inhabitants. (Statistical Office of Kosova 2015).[16] From all of them, 78% have access to water supply from Radoniqi Water Company, 6% are provided from other distribution systems and 16% have no access to any operational water supply system. Accordingly, approximately 27.350 people in the Municipality of Gjakova use drinking water from individual wells.

The sampling process is performed from staff of University of Gjakova, with strong involvement of the users’ community. Ethical permission has already been obtained for this study.

Based on all the facts mentioned, this study aims to perform a monitoring study in rural areas of the municipality of Gjakova (those areas not connected to public water supply) including chemical, microbiological and toxicological analysis.

Well water was exclusively used for drinking and other household uses,the wells are also mostly used for other activities (laundry,shower, etc),animal watering and irrigation.

The study is focused on monitoring indicators for faecal pollution, along with the common physical-chemical parameters, and specific pollutants like pesticides and heavy metals, as defined in the respective national and European regulations.

The study was conducted in Gjakova, in total there are 20 water samples collected from potable water wells in rural areas, as shown in Figure 1, in depth between 5 to

40 m. They include Gjakova, Blloku i Ri Orize, Marmul, Ramoc, Rracaj, Rrypaj, Dobrosh, Piskote, Kramovike, Qifllak, Zhabel, Jabllanice, Bardhaniq, Popoc, Ponoshec and Raqe.

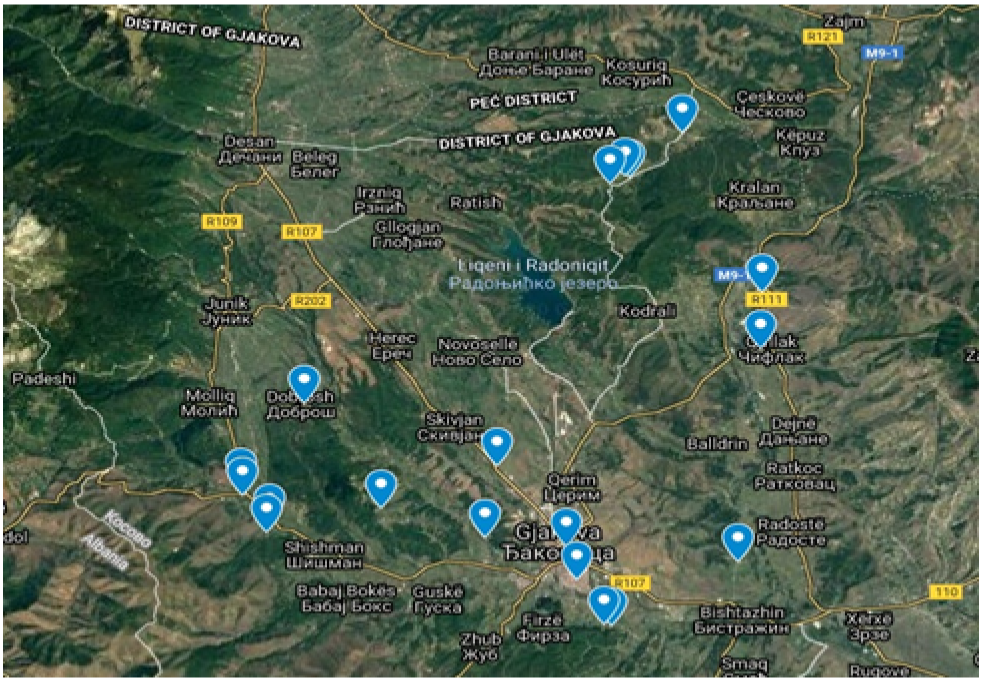

Figure 1 Map of sampling points

Sample collection

Water samples for physical-chemical analysis are collected in purified 2000 mL bottles. Water samples for pesticides, heavy metals were transported in cleaned and tightly sealed glass bottles. Water samples for microbiological analyses are collected in sterile 500 mL glass bottles. The water was taken from wells or taps that were connected to the well water and before sampling, the water was allowed to flow at a time interval of 15 minutes. The sample was kept sterilized bootless in an ice chest and transported to the laboratory at a temperature of 4-5°C. The bacteriological tests were undertaken within 6 h of collection to avoid death or growth of organisms in the sample.

Sample analysis procedure

Bacteriological analysis

Bacteriological quality is one of the important parameters of water potability. E-coli is one of the most determined bacteria that indicates faecal contamination.[17]

Total coliform and faecal coliform colonies were counted after 24 h of incubation at a temperature of 37^0C to total germs and 44^0C, respectively, using membrane filtration and membrane lauryl sulphate broth methods. Tests were conducted using 100 ml of water aseptically filtered through a nitrocellulose filter. After filtration, this membrane was placed in a Petri dish containing a standard culture medium TTC (trifenyl chloride tetrazolium) and Tergitol for total germs and E-coli.

The results were collected 48-72 hours after incubation. Yellow colonies for both total coliform and faecal coliform were counted using the colony counter.

The results are analyzed by considering the bacteriology for the detection and enumeration of faecal bacteria in water of the Drinking Water Directive 98/83/EC and Administrative Instruction No. 16/2012 which is obligatory for drinking water quality in Kosovo.

Physicochemical analysis

Water temperature was measured on the site using mercury thermometer, pH was measured using digital pH meter (ISOLAB).Turbidity was measured by Hanna using 1.2-2.4 NTU Standards. Hardness, residual chlorine are measured with volumetric methods and the other physicochemical parameters were measured with Photometer NOVA 60 A.

Analysis of heavy metals is performed by ICP-MS according to EPA 6020 A. Determination of Organ chlorine pesticides / 0.1 mcg / l was measured with GC SHIMADZU 2010, ECD.

Table 1. Physico-chemical and microbiological parameters

Partameter tested	Standard Method	Measuring unit	Measuring Range
Odor	ISO 2892-15		
Color	ISO 7887:1994	m-1	
Hardnes	ISO6059:1984	d°H	01-50
Free chlorine (residue)	ISO 7393-1:2000	mg/l	0.018-1.5
Chlorides	ISO9297:1989	mg/l	5-250
Turbidity	ISO 7027:2001	NTU	0.01-1000
Ph	ISO10523:2008		1.0-14.0
Conductivity	ISO27888:2001	µS/cm	0.01-2500
Iron-Fe	SMWW3500 Fe-B	mg/l	0.005-5.0
Manganese-Mn	ISO6333:1986	mg/l	0.01-10.0
Aluminium-Al	SMWW3500-Al	mg/l	0.020-1.20
Sulphate-SO_4^{2}	SMWW4500-SO_4^{2}	mg/l	10-250
Ammonia - NH_4^+	ISO7150-1:1986	mg/l	0.01-30
Nitrite - NO_2^-	ISO6777:1984	mg/l	0.002-1.00
Nitrate - NO_3^-	ISO7890-3:1988	mg/l	0.20-20.0
Det.of permangan indx.(O_2)	ISO8467:2000	mg/l	0.5-10
Calcium – Ca	ISO6059:19845	mg/l	0.05-250
Carbon dioxide - CO_2	SMWW4500CO_2	mg/l	400-7380
Magnesium -Mg	ISO6059:1984	mg/l	0.05
Nitrogen - N	SMWW4500-N	mg/l	0.5-15
Oxygen –O_2	SMWW2710-O	O_2mg/l	0.0-19.9
Phenols	SMWW5530-F	mg/l	0.001-0.25
Phosphorus-P	SMWW4500PO4^{3}	mg/l	0.01-5.0
Fluoride	SMWW4500-F-E	mg/l	0.10-1.5
Cyanide	SMWW4500-Cn	mg/l	0.002-0.50
Bikarbonate HCO_3	SMWW2320-B	mg/l	---
Carbonate –CO_3	SMWW2320-B	mg/l	---
Iodine-J	SMWW4500-J	mg/l	---
Total Organic Carbon -TOC	EU-En1484:1997	mg/l	0.50-10.0
Disolved Organik Carbon - DOC	EU-EN 1484:1997	mg/l	0.50-10.0
Total Organochlorine Pesticides	EPA methods 8081 A	mg/l	0.002-0.1
Total Suspended Solids	SMWW2540 D	mg/l	0.1-50
Bromate BrO_3	ISO 15061:1995	mg/l	0.003-0.120
Total Coliform bacteria	ISO 9388-1:2003	in 100ml	
Coliform Bacteria of faecal origin	ISO 9388-1:2003	in 100ml	
Total number of aerobic mesophylic bacteria	ISO 6222:1999	in 100ml	
Streptococcus of feacal origin	ISO 7899-2:2000	in 100ml	
Sulpide reducing anaerobic bacteria		in 100ml	
Pseudomonas aeruginosa		in 100ml	

Results and discussions

Physical-chemical parameters

Nearly 30 chemical physical parameters are analysed in total in water samples from 20 potable water wells, in rural places in Municipality of Gjakova during April 2020. For parameters cyanide, iodine, turbidity and phenols the concentration in all samples was shown to be lower than the limit of detection of the analytical method. The other parameters are summarized in Table 2. As it can be seen in this table, most of the samples are following the national regulation for the water quality for human consumption.

Table 2 Selected chemical-physical parameters, their median values in all water wells and comparison with the national regulation

Parameter	Unit	Complies [n, (%)]	Median values	Limits according to national regulation
Ammonium (NH4)	mg/l	18 (90%)	0.013	0.5
Bicarbonate (HCO3)	mg/l	---	36.7	---
Carbonate (CO3)	mg/l	---	18	---
Chloride (Cl)	mg/l	20 (100%)	7.5	250
Color	m^{-1}	20 (100%)		---
Conductivity	µS/cm	20 (100%)	360	2500
Fluorine (F)	mg/l	20 (100%)	0.05	1.5
Hardness	°dH	20 (100%)	11.42	---
Iron	µg/l	20(100%)	0.001	200
Manganese	µg/l	20(100%)	0.001	50
Nitrate (NO3)	mg/l	20 (100%)	3.36	50
Nitrite (NO2)	mg/l	20 (100%)	0.00495	0.5
Oxygen consumption	mg/l	20 (100%)	0.86	5
Oxygen content (O2)	mg/l	---	4.29	---
pH	---	20 (100%)	7.58	6.5-9.5
Phosphate (PO4)	mg/l	19 (95%)	0.02	1.5
Smell	---	20 (100%)		---
Sodium	µg/l	20(100%)	0.001	200
Sulphate (SO4)	mg/l	20 (100%)	3.55	0-250
TOC	mg/l	---	2.66	---

In the study done by Abdolmajid Fadaei et al (2014), the pH value of the water ranged from 6.62 to 8.72 (mean 7.60 +/- 0.21).The PH was below the Administrative instruction and EU directive acceptable level. [18] Similar with our finding the studies carried out by H. Adamou et al (2020), almost all samples had pH value within the WHO recommends. They also find abnormal concentrations of NO_2 and NO_3 in almost half of analysed samples, which may have great danger for the population, especially for the juvenile population.[19] High nitrate concentrations are reported in some groundwater studies in Nigeria, Morocco and Togo.[20,21,22] The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing changes in other water quality parameters such as solubility of metals and survival of pathogens. (Zabed et al,2014). [23] The turbidity value is below the permissible limits of 0.4-2.5 NTU. The analysis of free chlorine in all water wells show concentrations lower than limit of detection of the analytical method, confirming that no water disinfection is performed at all. The standards authorized by Administrative Instruction in Kosovo (16/2012) in drinking water for ammonium concentration are 0-0.5 mg/l. Very high ammonium concentrations (2.6 mg/l and higher) are observed in two water wells (Blloku Ri Orize & Marmul). These values strongly exceed the median of all collected samples (0.013mg/l) and the limit of the national regulation of 0.5mg/l. High ammonium concentrations in potable water wells are a common indicator of anthropogenic impact through organic waste disposal, leaking sewage systems or animal waste pollution. This could be confirmed for the well “Blloku i Ri Orize”, where the total number of coliform bacteria of faecal origin is significantly higher than the national limit. Additionally, both parameter TOC and oxygen demand in this sample show the highest values among all (6.1 and 3.4 mg/l respectively), confirming a very high bacterial load. Furthermore, the extremely high concentration of phosphate in this sample (1.55 mg/l) compared to the other samples (median: 0.02mg/l) is an additional confirmation for organic waste contamination as phosphorus is a common constituent of manure, and organic wastes in sewage and industrial effluent. Similar situation could be observed for the Qifllak well, which shows the highest microbiological contamination (values >300 cfu/100 ml for all four analysed parameters) and a significantly higher ammonium concentration compared to the other samples (0.182mg/l compared to the median 0.013mg/l). During the sampling, it was observed that the well was very shallow and poorly protected, so that surface water could easily penetrate into the well. Consequently, it can be concluded that these two potable wells are highly contaminated (chemically and microbiologically) and the source of contamination is probably leakage of waste water from sewage or animal waste. In the water sample from well "Marmul" on the contrary, though high ammonium concentration, no significant microbiological contamination is observed, so that the reason for the high ammonium concentration cannot be faecal pollution. The high ammonium concentration in this sample can be explained with its high nitrogen content (nitrate 45.4 mg/l) and its transformation to nitrite and ammonium under anaerobic conditions in this deep well (30 m). Both parameters are significantly increased in this sample (nitrite: 0.059 mg/l and ammonium 2.6mg/l), compared to the respective median values (0.005 mg/l and 0.013 mg/l). In this case, is supposed that the source of contamination is nitrate from agricultural use. Raised nitrogen levels in groundwater because of excessive usage of nitrogen-based fertilizers are known problems in many places in Europe. A team of scientists have recently calculated the dynamic of these fertilizers in groundwater, coming to the conclusion that nitrate can leach into the groundwater and surface water on about three-quarters of Europe's agricultural land over a period of at least four months per year. [24] The standards authorized by Administrative Instruction in Kosovo (16/2012) in drinking water for nitrate are 0-50 mg/l. There are rather high nitrate concentrations (35 - 45mg/l) observed in four water wells (Marmul, Dobrosh, Zhabel (1) and Jabllanice), but they are still below the threshold given in the national regulation (50mg/l). These samples are consequently showing higher nitrate-nitrite-index ([nitrate]/50+ [nitrite]/3), which must be lower than 1mg/l according to the national regulation. The calculated values for these samples are not exceeding this threshold but are between 0.7 and 0.9mg/l, which indicates a rather high nitrogen content in water. This is supposed to be a consequence of excess usage of fertilizers in this area. This is consistent with the studies carried out by Abdolmajid Fadaei et al (2014), where nitrate recorded a mean value of 15.5 mg/l. Min 7.4 mg/l and Max is 25.6 mg/l. [18] Similar to our study done by H Adamou et al (2020) [19], they had found at least twice the standard value for NO_2 and NO_3 concentrations. Most of these wells are shallow and poorly protected and can result in disease transmission. Studies have been focused on some main issues concerning well water, and those published about arsenic presence, bacteriological contamination, geological factors, health impact, public health importance, etc. Despite the law, the programs are used to increase the awareness of the households to test their water and contribute on public health.2[5,26]

Pesticides and heavy metals

As already mentioned pesticides represent a serious contamination source for potable water wells as they can penetrate through waste disposal, wastewater spills, and surface water run-off. People that consume high levels of pesticides and other organic chemicals may suffer from damage to their kidneys, liver, circulatory system, nervous system, and reproductive system. The concentration level of pesticides measured in this study resulted to be very low in all investigated wells. In total 15 pesticides and their metabolites are analysed in 20 water samples. The concentration of total pesticides analysed resulted to be under the limit of quantification of the analytical method (0.01- 0.05µg/l) for every water sample. Even the concentrations of the single substances were under the limit of quantification, except one (Methoxychlor in the well "Blloku i ri Orize" with 0.02µg/l), it can be concluded that the potable wells investigated are well protected from the penetration of these pesticides from the agricultural land use in the region. To investigate the well water quality in terms of heavy metals, in total 13 elements are analysed in all water wells. For Co, Al, As, Se, Sb, Hg, Ag no concentrations higher than the limit of quantification of the analytical method could be detected in For Co, Al, As, Se, Sb, Hg, Ag no concentration higher than the quantity limit of the analytical method expressed in µg/l of water can be detected. The results for Ni, Cr, Cd, Mn, Fe and Zn and the corresponding threshold values within recommended standards are shown on Table 3.

Table 3 Heavy metal concentration and the corresponding threshold from the national regulation in µg/l

Water well	Well depth	Ni	Cr	Cd	Mn	Fe	Zn
Gjakova	7m	<LOQ	<LOQ	0,07	0,70	1,29	244
Blloku i ri Orize	40 m	1,62	<LOQ	<LOQ	104	8,33	20,1
Marmul	30 m	<LOQ	<LOQ	<LOQ	10,2	1,05	15,3
Ramoc	15m	<LOQ	0,25	0,21	0,34	5,72	12,6
Rracaj	7 m	<LOQ	<LOQ	<LOQ	<LOQ	1,94	11,1
Rrypaj	6m	<LOQ	<LOQ	<LOQ	0,48	0,66	31,7
Dobrosh	22 m	<LOQ	<LOQ	<LOQ	4,66	3,66	60,7
Piskote	7 m	<LOQ	<LOQ	<LOQ	8,60	<LOQ	30,9
Kramovike	3-4 m	<LOQ	<LOQ	<LOQ	1,57	3,15	9,7
Qifllak	5 m	<LOQ	<LOQ	<LOQ	7,73	4,92	11,0
Zhabel-1	5.5 m	<LOQ	<LOQ	<LOQ	2,77	4,11	149
Zhabel-2	6 m	<LOQ	<LOQ	<LOQ	8,89	2,37	22,5
Jabllanice	13 m	<LOQ	<LOQ	<LOQ	30,4	2,09	11,4
Bardhaniq	7 m	<LOQ	<LOQ	<LOQ	71,9	2,55	5,9
Popoc-1	14 m	<LOQ	<LOQ	<LOQ	3,28	4,96	3,5
Popoc-2	22 m	<LOQ	<LOQ	<LOQ	0,73	10,9	331
Ponoshec-1	7 m	<LOQ	<LOQ	<LOQ	0,80	1,08	1,8
Ponoshec-2	8 m	<LOQ	<LOQ	<LOQ	0,47	1,32	9,2
Raqe-1	5 m	<LOQ	<LOQ	<LOQ	3,10	1,25	30,8
Raqe-2	8 m	<LOQ	<LOQ	<LOQ	0,59	2,54	27,6
Threshold		20	50	5	50	200	3000

As it can be seen on this table, the measured concentrations of Ni, Cr, Cd in three samples (all the others are <LOQ) are very low compared to the corresponding threshold values. The same conclusion can be reached for iron and zinc. In case of manganese there are two water samples exceeding the threshold value of 50 µg/l, from wells Blloku i ri Orize and Bardhaniq. Based on this research we can conclude that the potable waters wells investigated in this study do not show any kind of heavy metal contamination. Similar to our study we found the findings in research from Abdolmaid and al (2014),[18] where the As, Zn, Cu, Se, Cr, Mo, Sb and V contents were found below the permissible limit.

Microbiological analysis

In countries with low income such as Kosovo, the majority of the population is not adequately supplied with safe drinking water and quality from network water supply, that's why they use well water for drinking, domestic and other purposes. Unfortunately their wells are unprotected and ill- managed from individual households and may be unsafe for drinking and domestic application as a result of contamination through different sources of pollution. The most common water quality problem in rural water supply in Gjakova is bacterial contamination with Escherichia Coli, Streptococcal bacteria with fecal origin, coliform bacteria with fecal origin and mesophyll bacteria where from total 20 samples 5 are contaminated. Table 4 illustrates the relationship between the levels of bacteriological contaminants detected in the well in relation to the improper way of building wells and their improper depth. Another reason is the non-treatment of these resources neither by the municipal level nor by the owners of their use.

Table 4. Micro-biological analysis

	Complies [n, (%)]	Values (mg/l)	Excessive levels (fold)	Limits Ks regulation [mg/l]
Escherichia coli*	19 (95%)	15.50 ± 67.00	1.55	0-10
Enterococcus*	18 (90%)	20.00 ± 69.58	20	0
Coliform bacteria*	15 (75%)	43.68 ± 95.46	4.37	0-10
Total number of live bacteria	17 (85%)	70.00 ± 107.31	N / A	0-100

*in 100ml water

Most of these wells are shallow and poorly protected and can result in disease transmission. Studies have been focused on some main issues concerning well water, and those published about arsenic presence, bacteriological contamination, geological factors, health impact, public health importance, etc. Despite the law, the programs are used to increase the awareness of the households to test their water and contribute to public health.2[7] Furthermore, some authors found that they tend not to test their own wells. The positive samples for Escherichia Coli are found at a high number, and for the purpose of these highly contaminated wells and boreholes, the recommendations are to treat the water before consumptions.2[8] The contamination (Escherichia Coli and other resistant bacteria) is related to the use of dug or shallow wells and alerts the immediate action toward sanitation improvement and coordinate the public health policies.[29]

Similar to our study a study done in Brazilian cities by Nayara Maran et al during 2016, found that 33% of the water was contaminated with E.coli.[28] Also a very valuable study done in Bekasi City shows that contamination of well water has occurred in 24% of samples taken poses a very high risk of contamination with E.coli.[30] Based on another study done in 2018, it is clear that the presence of Escherichia coli is not detected in most of the analysis, but it was present in samples collected in the rainy season.[31] Presence of Escherichia coli, clostridium perfringens, and staphylococcus aureus was found as well in another study in Kenia with 36.8 % of the 20 surface water samples tested negative , but in 22.9% of the ground water sources were positive in this three bacteria.[32] From another study in South Africa research showed the positive correlation in a total 144 samples, where all the wells sampled in this study recorded mean E.coli count above the WHO and the South African recommended limits for drinking water.[33] Similar to our study a study done in Iran from Abdolmaid Fadaci et al (2014), found that total coliform bacteria in drinking water samples generally exceeded the permissible limit. That contamination may be due to leakage/discharge from septic tanks, lack of sewage and solid waste disposal systems which were the main threat to water sources. [18] In the study done by Jeremiah. K et al, (2018) in Ghana, were found to have bacteriological contaminations in relatively higher numbers of groundwater sources. From these contaminants in most of the samples non-faecal coliforms, salmonella, E.coli, and faecal coliforms were found.[34] In recent study conducted in Nepal from (Rai et al., 2012), it was reported that out of the total 506 water samples studied 88,5 % samples were positive for total coliform, whereas 56.5% were positive for faecal coliform particularly E.coli bacteria.[35]

Conclusions

From the results of the study, it can be concluded that according to our standards private potable water wells do not receive the same services as the public ones. In these cases the well owners are responsible for the quality of their drinking water and they must be aware of existing contamination potential and its possible health effects. Level of micro-bacterial contaminants were found in 5 samples and collected in rural areas in Municipality of Gjakova, for this reason these resources are not wholly safe for human consumption. The groundwater is not only faecal polluted but could also be potentially infectious, especially for children, the elderly and immunocompromised individuals. It is therefore recommended that water quality analysis be carried out on all wells in this area at least once a year to monitor the bacterial contaminations that were relatively high or low. In terms of chemical-physical parameters according to the results most of the samples (18 from 20) fit the national water quality regulation for human consumption and no serious problems with the chemical water quality could be identified. The water quality in two wells (Blloku i Ri Orize & Marmul) is strongly contaminated with ammonium, exceeding the limit of the national regulation. This fact, in combination with the strong microbial pollution found in these wells leads to the conclusion of a strong anthropogenic impact through organic waste. In accordance with the observation that these wells were very shallow and bad protected, it can be concluded that the source of contamination is probably leakage of wastewater from sewage or animal waste. An enhancement of nitrate concentrations (35 - 45mg/l) is observed in four water wells. Even though these are still below the threshold given in the national regulation and no immediate measures are necessary. It is supposed to be a consequence of excess usage of fertilizers in this area. The analysis of free chlorine in all water wells shows concentrations lower than the limit of detection of the analytical method in every sample, confirming that no water disinfection is performed at any water well. This is important information in regard to microbiological water quality. From the analysis of 15 pesticides according to the national regulation in all samples, it can be stated that the concentration of total pesticides resulted to be under the limit of detection of the analytical method for every water well. Even the concentrations of the single substances were under the limit of quantification, with one single exception. Therefore, it can be concluded that the potable wells investigated are well protected from the penetration of these pesticides from the agricultural land use in the region. In terms of heavy metals, for most of them (Co, Al, As, Se, Sb, Hg, Ag) no concentrations higher than the limit of quantification of the analytical method could be detected in any of the samples. Only Ni, Cr and Cd in three samples were detected, but their concentration is very low compared to the corresponding threshold values. The same conclusion can be done for iron and zinc. Manganese was the only metal exceeding the threshold value from the national regulation in two water samples. Based on these results, it can be concluded that the potable waters wells investigated in this study do not show any serious heavy metal contamination. The same research should be done in the winter season on purpose to raise awareness about the potential hazards of well water among local community leaders and empower many residents to test their water. This study highlights the need to involve users` communities at every single stage of drinking water supply using potable water wells, to ensure a long-term success on safe drinking water and health protection. Therefore, a large-scale distribution of water from the small drinking water supply system and the application of chemical disinfectants are alternative solutions for improving access to safe drinking water in rural areas, such as Gjakova. It is a strong responsibility of public health authority in Kosovo to raise this awareness and to make people change their behavior regarding drinking water protection in private potable water wells. As the risk is not the same for everyone but varies in complex ways depending on several dimensions (e.g., location, soil type, well structure) educational campaigns are of utmost importance and should be performed properly and regularly from the responsible authorities. Further extended studies regarding seasonal and regional variations in Kosovo are strongly recommended to achieve the above-mentioned goals.

Author Contributions

Announcements for individual contributions: idea, A.U. and R.A.; methods, A.U.; software, A.B.; validation, N.R., D.Z. and R.A.; writing—original draft preparation, A.U.; writing—review and editing, R.A.; idea, visualization, D.K.; funding achievement, A.U. All authors have read and agreed to the published version of the manuscript.

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