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Quality Assessment of Well Waters in the Gollak Mountain (Kosovo) and Correlation Coefficients Study between Chemical Parameters.

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ABSTRACT

In this study the assessment of water quality and correlation coefficients between different pairs of variables in 5 well water samples (depth 60 to 180 meters) in the Gollak Mt. (district of Prishtina) were investigated. Concentrations of some ions are determined using UV-VIS spectrometry and atomic absorption spectrometry. Statistical studies have been carried out by calculating of basic statistical parameters, anomalies (extremes and outliers) and correlation coefficients between different pairs of variables. The statistical regression analysis shows that EC correlate high positively with pH, alkalinity, hardness, Cl^-, HCO_3^-, Mg^{2+}, Ca^{2+} and Mn^{2+}. pH showed a high positive correlation relationship with alkalinity, hardness, Cl^-, HCO_3^- and Ca^{2+}. In comparison with available results of three similar well waters in Kosovo, it can be summarized that water quality of well waters of Gollak Mt. were approximately the similarly with well waters of Mirosala. From the results of field work and laboratory analyses it was found out that well waters of Gollak Mt. are in high quality and fulfill the World Health Organization criteria set for drinking waters and can be used as drink water.

Keywords: Quality assessment, correlation coefficients, Gollak well waters, atomic absorption spectrometry.

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INTRODUCTION

Drinking water is water pure enough to be consumed or used with low risk of immediate or long term harm [1]. Well water represents an important source of drinking water and its quality is currently threatened by a combination of overexploitation and microbiological and chemical contamination. More than a billion people do not have access to safe water supplies and well over 2 billion people live without adequate sanitation. At any given time, more than half of the developing world's population is suffering from one or more of the main diseases associated with unsafe water and poor sanitation. More than four billion cases of diarrhea cause 2.2 million deaths, mostly of children under the age of five [2]. The sources of physico-chemical contamination are numerous and include the land disposal of sewage effluents, sludge and solid waste, septic tank effluent, urban runoff and agricultural, mining and industrial practices [3,4]. Chemical contamination of drinking water is often considered a lower priority than microbial contamination by regulators, because adverse health effects from chemical contaminations are generally associated with long-term exposures, whereas the effects from microbial contamination are usually immediate practices [5]. The quality of drinking water is an issue of primary interest for the residents of the European Union [6]. In peat bogs, water flows freely in the active layer of water or acrotelm. Water storage is critical to the balance of water in peat swamps and at surrounding areas. Logging activity, agriculture, peat extraction and destruction of peat swamp drainage activity also give a negative effect and has a bad implication on the hydrology [7]. Decomposition of organic matter and pollution due to anthropogenic activity are the main sources of pollution of water [8]. Therefore, multidisciplinary collaborative research is essential for understanding the pollution processes. As reported by Brils [9] adequate water quality in Europe is one of the most eminent concerns for the future. Good management of natural and environmental waters will give results if leading institutions constantly monitor information about environmental situation. Therefore, seeing it as a challenge for environmental chemists, our goal is to determine the amount and nature of pollutants in the environment. Heavy metals are significant environmental pollutants, and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons [10]. Heavy metals have largest availability in soil and aquatic ecosystems and to a relatively smaller proportion in atmosphere as particulate or vapors. Heavy metal toxicity in plants varies with plant species, specific metal, concentration, chemical form and soil composition and pH, as many heavy metals are considered to be essential for plant growth. Some of these heavy metals like Cu and Zn either serve as cofactor and activators of enzyme reactions e.g., informing enzymes/substrate metal complex [11]. Mining activities are one of the most important and abundant source of metal contamination of ecosystems. These activities can affect small areas, but could have a significant impact on the environment, and they are considered to have the potential for causing heavy metal pollution and associated diseases [12]. The past mining activities have generated large volumes of waste rocks and concentrator tailings without any security and environmental protections and many researchers worldwide have focused on and reported assessments of heavy metal concentrations [13,14].

Animals that graze on such contaminated plants and drink from polluted waters as well as marine lives that breed in heavy metal polluted waters also accumulate such metals in their tissues and milk [15]. Some of the heavy metals are easily transported from surface to ground water [16]. Potable and safe water gradually became scarce commodity, due to mixing up of huge contaminants through natural process like soil and rock weathering and anthropogenic activities such as industrial effluents, domestic sewage, garbage, over mining activity, explosive population etc [17,18]. Metalic elements are environmentally stable. They can enter in living system through an aquatic medium and accumulated up to prolong period, resulting acute adverse effects on human being, animals and plants. Metallic elements have significant role to increase the degradation of water quality via thermal power plant, extraction of metals, transpiration, over application of fertilizers, pesticides and insecticides. Some heavy metals such as Cu, Fe, Mn, Ni and Zn are compulsory as micro nutrients for flora – fauna and microbes. Traces of metals in natural waters allocate between dissolved species and species bound to particular (colloid) particles. Interaction of dissolved traces of metals, as sediment and biota, depend on physico-chemical characteristics of their chemical species. For better understanding of processes which control cycling of trace metals between certain components in water it is necessary to know their distribution and concentration of their particular species [19-21].

Mainly there are four main approaches that can be used to assess the water quality of a water body: (1) water quality index approach, (2) trophic status index approach, (3) statistical analysis approaches of the water quality data such as correlation analysis and (4) biological analysis approaches such as Genetic Algorithms method and other different biological indices [22]. Literature has also shown that multivariate statistical methods have been proved to be one of the most useful tools for extracting meaningful information from data sets. For example applied cluster analysis (CA) to delineate monitoring sites of surface/drinking water quality while used CA and discriminant analysis (DA) to identify significant parameters and optimize monitoring network of ground water quality data [23-26].

Until recently, the waters of Kosovo have been poorly investigated. Gashi et al. [27] performed first step with investigation of the rivers Drini i Bardhë, Morava e Binçës, Lepenc and Sitnica, which are of supra-regional interest. They performed investigations of mineralogical and geochemical composition and of contamination status of stream sediments of mentioned rivers of Kosovo. By comparing the concentrations of toxic elements with the existing criteria for sediment quality, in that study was found that two sites in Sitnica River are significantly polluted, especially locations in Fushë Kosova (Kosovo Polje) and in Mitrovica. This was assumed to be caused by Zn and Pb processing by flotation and Zn-electrolysis factory. In Morava e Binçës River, two sites were found to be polluted with Cd. The authors of that paper suggested future monitoring of sediments and possibly remediation of Sitnica and Morava e Binçës rivers. As Drenica River is the most important tributaryof Sitnica River, the current paper presents next step in detailed investigation and monitoring of Sitnica river watershed, which is most polluted river system in Kosovo. Gashi et al. [28-30] performed research of mass concentrations of ecotoxic metals: Cu(II), Pb(II), Cd(II), Zn(II) andMn(II) in waters of four main rivers of Kosovo. The main goal of that work was to suggest to authorities concerned a monitoring network on main rivers of Kosovo (Drini i Bardhë, Morava e Binçës, Lepenc and Sitnica). The authors also aimed to suggest application of WFD (Water Framework Directive) in Kosovo as soon as possible and performed research could be the first step towardsit, giving an opportunity to plan the monitoring network in which pollution locations will be highlighted. The authors highlighted two locations in Sitnica River as very polluted with ecotoxic elements and possible remediation by Kosovo authorities concerned was suggested. Gashi et al. [31] performed investigation of the distribution of some metals in sediments and waters from Drenica river. Sediment quality in the Drenica River has been and is currently under the influence of various factors. Based on the values of the content of heavy metals in the water and sediment resulting in locations taken in the study, it can be said that a nickel refining plant is the main polluter of Drenica River. Troni et al. [32] compared the surface water quality in Kosovo in Lumbardhi River basin in the region of Peja. From chemical aspects are investigated some of main indicators pollution as: pH value (in situ), dissolved oxygen, lead, cadmium, copper, zinc, arsenic, cobalt, nickel, uranium, bromine, nitrites, etc. Based on Croatian standards for drinking water, the Lumbardhi River water was classified in first and second class according to the concentrations of zinc and cadmium.

STUDY AREA

The aim of the current work is to perform, a systematic research of the well waters quality in the Goljak region, in the District of Prishtina (Fig. 1). Gollak is a mountainous region in the eastern part of Kosovo and southern Serbia [33]. Although there are more than 50 water quality parameters available, only 29 parameters are selected for our investigation. These parameters are: water temperature, conductivity, pH, consumption of $KMnO_4$, concentration of ammonia, nitrite, ammonia, etc. The results are interpreted using modern statistical methods that can be used to locate pollution sources. The levels of some physico-chemical parameters of well waters are compared with the World Health Organization statndards for drinking water [34,35]. Finally that value of 29 parameters of well waters were compared with values of 5 well waters in Kosovo.

Sampling and sample preparation

For chemical analysis water samples are collected on May 29, 2012. Samples, previously were rinsed three times with sampled water, and labeled with the date and the name of the sample. These samples are transferred to refrigerator (at 4 °C) for analysis in the laboratories. All tests are performed at least thrice to calculate the average value. Sampling, preservation and experimental procedure for the water samples are carried out according to the standard methods for examination of water [36-38]. Samples are preserved in refrigerator after treatment.

Figure 1. Map showing the location of the study area and positions of sampling stations.

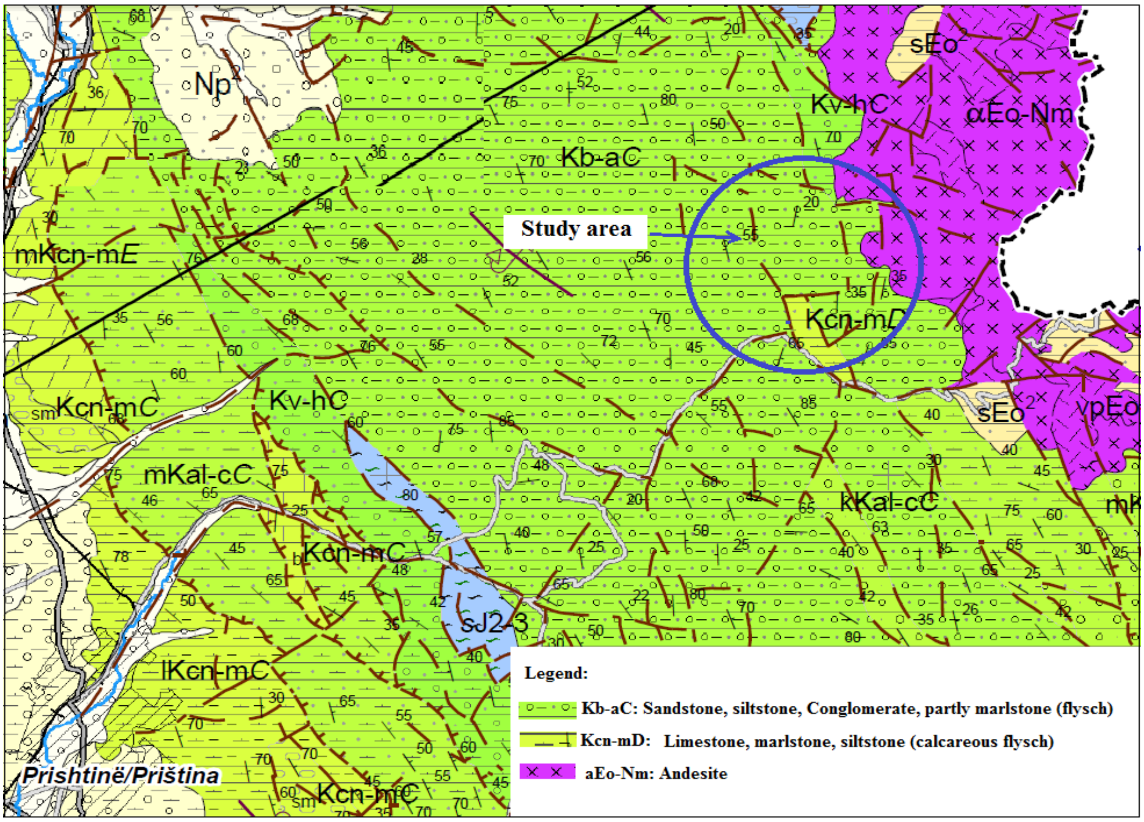

Figure 2. Geological map of the studied area, constructed after Geological map of Kosovo (Independent Commission for Mines and Minerals, 2006).

Chemical characterization

Double distilled water was used in all experiments. All instruments are calibrated according to manufacturer's recommendations. Temperature of water was measured immediately after sampling. TDS and pH measurements were performed using pH/ion-meter of Hanna Instruments. Turbidity was measured using „Turbidimeter 340i". Electrical conductivity was measured by „InoLab WTW" conductometer. Depending on chemical reactions with volumetric titration (acidimetry, alkalimetry, complexometry, argentometry and oxidoreduction) methods were defined concentration of calcium, magnesium, chlorides and chemical consumption of $KMnO_4$ (Thiemann Küebel volumetric method, boiling in acidic environment). Concentrations of H_2S (in 665 nm), PO_4^{3-} (in 880 nm), NO_2^-(in 507 nm), NO_3^- (in 500 nm) and NH_4^+(in 655 nm) were determined using UV-VIS spectrometry method, using „SECOMAM Prim light" SECOMAM pastel UV and „Hach 2800 Spectrophotometer". Metals in water were analyzed using atomic absorption spectrometer model ''Perkin Elmer, AAS Analyst 400, HGA 900.'' The ISO 6351 procedure was fol-lowed. Accuracy of determination was ±10 %, and limits of detection (LOD) were as follows: Al (0.1 mgL^{-1}), Ni (0.006 mgL^{-1}), Cu (0.0015 mgL^{-1}), Zn (0.0015 mgL^{-1}), Fe (0.005 mgL^{-1}), Mn (0.0015 mgL^{-1}), and Cr (0.003 mgL^{-1}).

Statistical methods

Program Statistica 6.0 [39] was used for the statistical calculations in this work, such as: descriptive statistics, Pearson's correlation factor and two dimensional box plot diagrams for determination of anomalies (extremes and outliers) for solution data. Relationships between the observed variables were tested by means of correlation analysis. The level of significance was set at $p < 0.05$ for all statistical analyses. It was qualitatively assumed that the absolute values of r between 0.3 and 0.7 indicate good association, and those between 0.7 and 1.0 strong association between elements.

RESULTS AND DISCUSSION

The physico-chemical parameters of 6 well water samples, i.e. water temperature, EC, pH, TDS, consumption of $KMnO_4$, hardness, alkalinity, and concentrations of CO_3^{2-}, HCO_3^-, NH_4^+, NO_2^-, NO_3^-, Cl^-, PO_4^{3-}, Mg^{2+} and Ca^{2+} were presented in Table 2.The Descriptive statistics summary of the selected variables at water samples are presented in Table 3. For each variable, the values are given as arithmetic mean, geometric mean, median, minimal and maximal concentration, variance and standard deviation. **S**catter box plot diagrams of 15 measured variables are presented in Fig. 2. Using experimental data (Table 1 and 2) and box plot approach of Tukey [40], anomalous values (extremes and outliers) of 15 variables were determinate (Table 4). Correlation Pearson's factor for 12 variables was calculated to see if some of the parameters were interrelated with each other and the results are presented in Table 5.

Table 1. Sampling stations with detailed locality description

Sample	Coordinates	Height over sea /m	Surface water depth /m
S_1	N42°43'47.1036 E 21°16'26.1912	1067	180
S_2	N 42°43'45.5484 E 21°16'26.1732	1080	60
S_3	N 42°43'45.3972 E 21°16'28.0272	1082	150
S_4	N 42°43'44.184 E 21°16'29.262	1070	130
S_5	N 42°43'43.9572 E 21°16'27.7176	1061	90

Table 2. Some physico-chemical parameters of well waters

Parameter	Unite	WHO, standard	S_1	S_2	S_3	S_4	S_5	After treat. With O_3
Temp.	/°C	-	8.8	9.5	9.3	9	8.2	10.2
EC	/µscm^{-1}	1000	523	489	413	366	411	400
Turbidity	/NTU	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Era	/1	no	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
pH	/1	6.5-8.5	7.93	7.84	7.79	7.83	7.78	7.50
Alkalinity, total	/mgL^{-1}	250	40	40	32	29	33	38

Hardness, total	/° dH	30	13.44	13.44	10.96	9.52	10.64	8.4
Acidity	$/mgL^{-1}$	-	0.0125	0.0175	0.0175	0.0125	0.0125	0.0145
DO	$/mgL^{-1}$	-	5.5	4.2	6.35	6	5.2	5.9
Con. of $KMnO_4$	$/mgL^{-1}$	10	1.55	1.86	1.86	1.86	1.24	1.55
NH_3	$/mgL^{-1}$	1.5	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.0012
H_2S	$/mgL^{-1}$	-	0.008	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015
NO_3^-	$/mgL^{-1}$	50	0.3	0.2	0.3	0.5	0.8	0.3
NO_2^-	$/mgL^{-1}$	3	0.003	0.008	0.003	0.005	0.003	<0.0015
HCO_3^-	$/mgL^{-1}$	643	341.6	268.5	268.5	268	281.82	274.5
SO_4^{2-}	$/mgL^{-1}$	400	21	20	12	17	21	8
PO_4^{3-}	$/mgL^{-1}$	-	0.2	0.13	0.2	0.67	1.51	0.08
F^-	$/mgL^{-1}$	1.5	<0.001	<0.001	<0.001	0.14	<0.001	0.01
Cl^-	$/mgL^{-1}$	250	25	10	5	8	6	7.09
Br^-	$/mgL^{-1}$	-	0.04	0.05	0.11	0.07	0.05	0.06

Table 3. Concetration of some metals of well waters

Parameter	**Unite**	**WHO, standard**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**After treat. With O_3)**
Ca^{2+}	$/mgL^{-1}$	200	54	52.1	51	46	43.68	36.1
Mg^{2+}	$/mgL^{-1}$	150	21.87	23.2	22.4	19	19.63	14.6
Al^{3+}	$/mgL^{-1}$	0.2	<0.0015	<0.0015	<0.0015	<0.0015	0.01	<0.0015
Cu^{2+}	$/mgL^{-1}$	2	<0.0015	<0.0015	0.01	<0.0015	<0.0015	0.013
Fe^{2+}	$/mgL^{-1}$	0.3	0.001	0.01	0.02	0.009	0.02	0.01
Cr^{3+}	$/mgL^{-1}$	0.05	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.0015
Zn^{2+}	$/mgL^{-1}$	5	0.027	0.022	0.031	0.047	0.04	0.025
Ni^{2+}	$/mgL^{-1}$	5	0.027	0.022	0.031	0.047	0.04	0.01
Mn^{2+}	$/mgL^{-1}$	0.1	0.001	0.022	0.001	0.008	0.001	0.012

Table 4. Descriptive statistics of the 20 variables in 5 cases

Variable	Descriptive statistics						
	Mean	Geometric	Median	Minimum	Maximum	Variance	Std. Dev.
Water temp. /°C	8.9600	8.9485	9.0000	8.2000	9.5000	0.253	0.50299
EC $/\mu scm^{-1}$	440.4000	436.7337	413.0000	366.0000	523.0000	4083.800	63.90462
pH /1	7.8340	7.8338	7.8300	7.7800	7.9300	0.004	0.05941
Alkalinity $/mgL^{-1}$	34.8000	34.5173	33.0000	29.0000	40.0000	24.700	4.96991
Hardness /°dH	11.6000	11.4931	10.9600	9.5200	13.4400	3.107	1.76273
Acidity $/mgL^{-1}$	0.0145	0.0143	0.0125	0.0125	0.0175	0.000	0.00274
DO $/mgL^{-1}$	5.4500	5.3964	5.5000	4.2000	6.3500	0.685	0.82765
Co. of. $KMnO_4$ $/mgL^{-1}$	1.6740	1.6537	1.8600	1.2400	1.8600	0.077	0.27727
NO_3^- $/mgL^{-1}$	0.4200	0.3728	0.3000	0.2000	0.8000	0.057	0.23875
NO_2^- $/mgL^{-1}$	0.0044	0.0040	0.0030	0.0030	0.0080	0.000	0.00219

SO_4^{2-} /mgL^{-1}	18.2000	17.8246	20.0000	12.0000	21.0000	14.700	3.83406
PO_4^{3-} /mgL^{-1}	0.5420	0.3501	0.2000	0.1300	1.5100	0.339	0.58247
Cl^- /mgL^{-1}	10.8000	9.0288	8.0000	5.0000	25.0000	66.700	8.16701
Br^- /mgL^{-1}	0.0640	0.0599	0.0500	0.0400	0.1100	0.001	0.02793
HCO_3^- /mgL^{-1}	285.6840	284.3823	268.5000	268.0000	341.6000	1011.208	31.79950
Ca^{2+} /mgL^{-1}	49.3560	49.2004	51.0000	43.6800	54.0000	18.820	4.33817
Mg^{2+} /mgL^{-1}	21.2200	21.1569	21.8700	19.0000	23.2000	3.298	1.81603
Fe^{2+} /mgL^{-1}	0.0120	0.0082	0.0100	0.0010	0.0200	0.000	0.00809
Zn^{2+} /mgL^{-1}	0.0334	0.0322	0.0310	0.0220	0.0470	0.000	0.01006
Mn^{2+} /mgL^{-1}	0.0066	0.0028	0.0010	0.0010	0.0220	0.000	0.00913

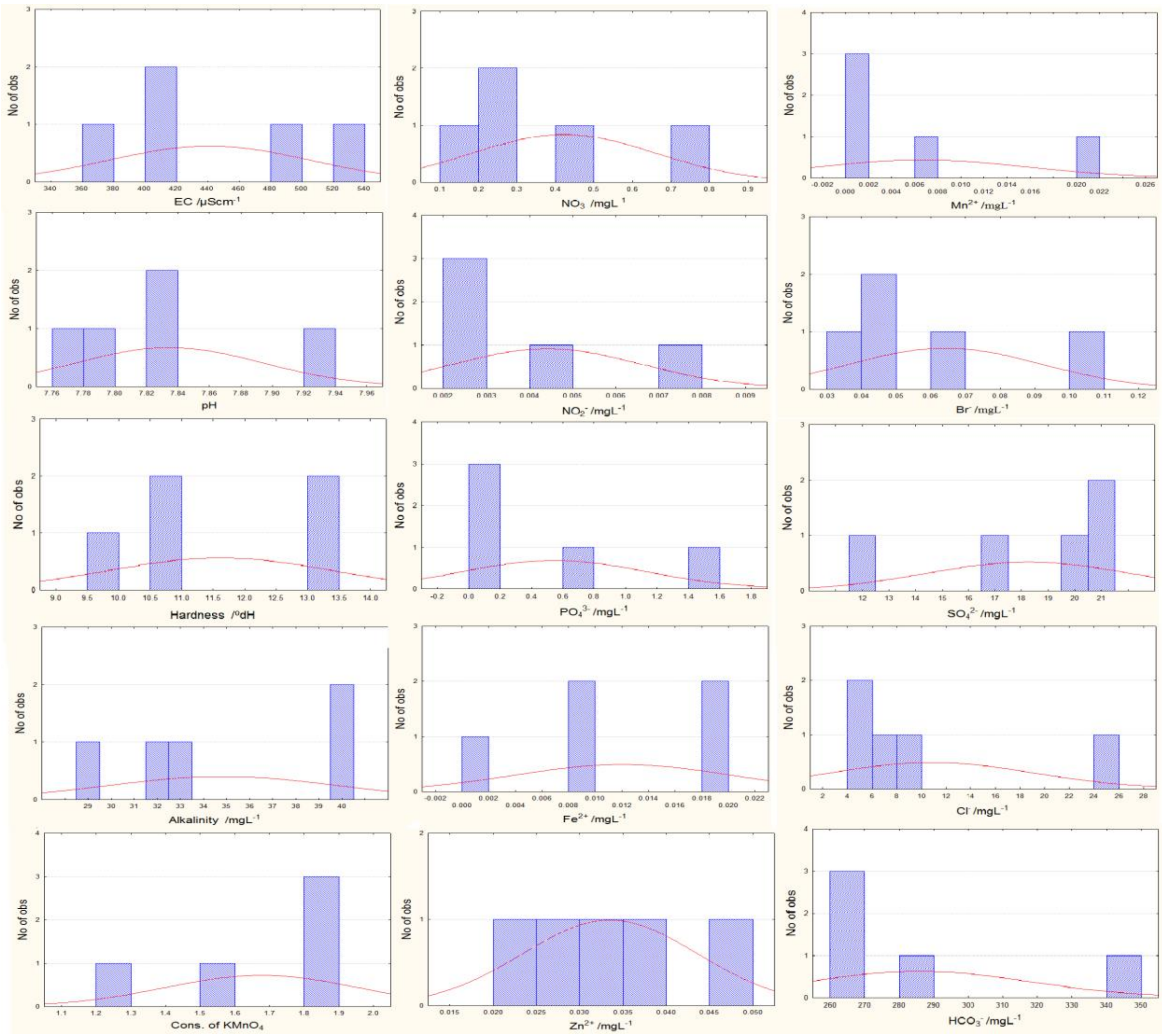

Figure 3. Frequency histograms of 15 measured variables.

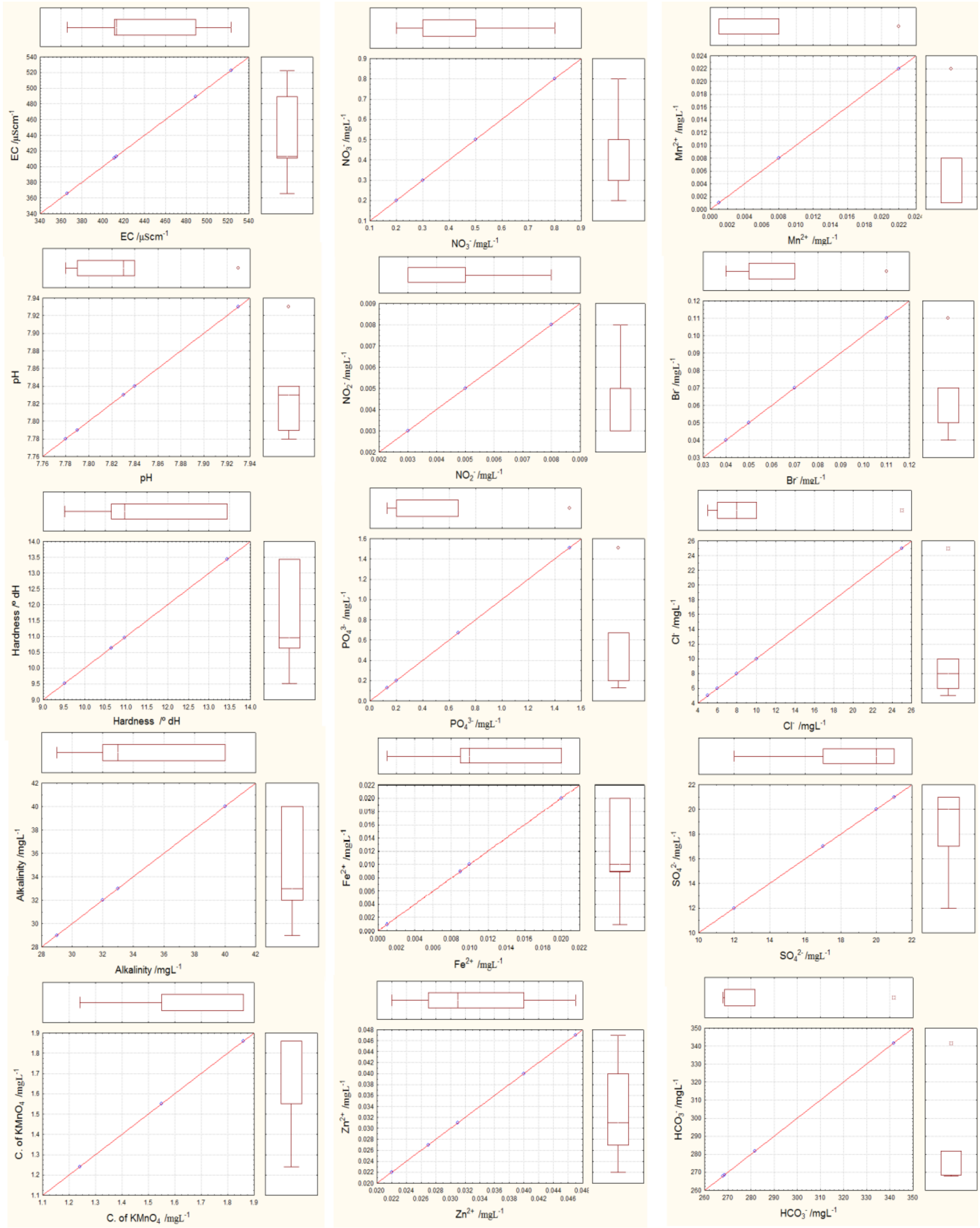

Figure 4. Scatter box plot diagrams of 15 measured variables.

Table 4. Anomalous values (extremes and outliers) determined in well waters

Sample	Extremes of parameters (¤)	Outliers of parameters (o)
S_1	HCO_3^- (341.6 mgL^{-1}), Cl^- (25 mgL^{-1})	pH (7.93)
S_2	No reg.	Mn^{2+} (0.022 mgL^{-1})
S_3	No reg.	Br^- (0.11mgL^{-1})
S_4	No reg.	No reg.
S_5	No reg.	PO_4^{3-} (341.6 mgL^{-1})

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Table 5. Matrix of correlation coefficients (r) of selected 19 variables

Variable	EC	pH	NO_3^-	NO_2^-	SO_4^{2-}	PO_4^{3-}	Cl^-	HCO_3^-	Alkalinity	Hardness	Acidity	DO	Cons. of $KMnO_4$	Ca^{2+}	Mg^{2+}	Fe^{2+}	Br^-	Zn^{2+}	Mn^{2+}
EC	1.00																		
pH	0.74	1.00																	
NO_3^-	-0.56	-0.50	1.00																
NO_2^-	0.17	0.04	-0.45	1.00															
SO_4^{2-}	0.51	0.45	0.27	0.20	1.00														
PO_4^{3-}	-0.52	-0.53	0.99	-0.35	0.33	1.00													
Cl^-	0.79	0.97	-0.37	-0.13	0.51	-0.40	1.00												
HCO_3^-	0.70	0.83	-0.12	-0.44	0.50	-0.16	0.94	1.00											
Akalinity	0.98	0.66	-0.54	0.33	0.57	-0.47	0.68	0.57	1.00										
Hardness	0.98	0.66	-0.64	0.33	0.45	-0.58	0.67	0.55	0.99	1.00									
Acidity	0.15	-0.29	-0.65	0.46	-0.52	-0.59	-0.37	-0.49	0.22	0.31	1.00								
DO	-0.54	-0.16	0.14	-0.71	-0.71	0.01	-0.14	0.00	-0.70	-0.63	-0.19	1.00							
Cons. of $KMnO_4$	-0.10	0.06	-0.75	0.54	-0.61	-0.76	-0.16	-0.42	-0.09	0.01	0.61	0.15	1.00						
Ca^{2+}	0.80	0.69	-0.91	0.18	-0.06	-0.91	0.64	0.48	0.74	0.82	0.46	-0.15	0.43	1.00					
Mg^{2+}	0.71	0.27	-0.83	0.34	-0.13	-0.77	0.25	0.12	0.72	0.80	0.79	-0.37	0.39	0.85	1.00				
Fe^{2+}	-0.60	-0.96	0.47	-0.23	-0.47	0.49	-0.87	-0.68	-0.54	-0.53	0.34	0.21	-0.17	-0.56	-0.13	1.00			
Br^-	-0.55	-0.55	-0.16	-0.24	-0.99	-0.22	-0.60	-0.55	-0.61	-0.50	0.52	0.70	0.52	-0.03	0.10	0.59	1.00		
Zn^{2+}	-0.86	-0.41	0.74	-0.34	-0.14	0.68	-0.42	-0.30	-0.88	-0.93	-0.63	0.53	-0.19	-0.85	-0.96	0.26	0.17	1.00	
Mn^{2+}	0.21	0.05	-0.47	1.00	0.21	-0.36	-0.12	-0.42	0.38	0.37	0.49	-0.74	0.51	0.22	0.39	-0.21	-0.25	-0.39	1.00

Discussion of physico-chemical parameters of well waters

In the present study, the temperature of 5 of well water samples varied from 8.2–9.5° C, as usual behavior of most of well waters. As thermostat adjustment of the instrument for conductivity measurement wasn't done, temperature of water sample was measured and with approximate correction factor, f, which for water, in temperature range from 10 to 25° C, is 0.02° C^{-1}, it was calculated to temperature of 20° C by the equation:

$$\kappa_{20} = \kappa_t \left[1 + f\left(20 - t\right)\right]$$

The electrical conductivity (EC) of well water samples varied from 366-523 µScm^{-1} as sign of natural pollution, and were higher than values measured value of Izbitac karstic spring on the slopes of Biokovo Mt. in Croatia (362.5 µScm^{-1}), which is known to be under the significant anthropogenic influence [41]. Turbidity values in all water samples were under 0.01 NTU and not exceed recommended WHO norms for drinking waters. pH values were varied from 7.78-7.83 and It could be from composition of rocks in that area. Total alkalinity (calculated as $CaCO_3$) was ranging from 29-40 mgL^{-1} and were found to be under recommended World Health Organization standards for drinking water (80 mgL^{-1}). Concentration of HCO_3^- was ranging from 268-341.6 mgL^{-1} and all stations were found to be under recommended standards for drinking water (WHO standard, 635 mgL^{-1}), what could be due to carbonate abundance around this location. Total hardness was ranging from 9.52-13.44° dH und were found to be under recommended standards for drinking water (30° dH). Increased hardness on those locations is of natural origin, due to presence of sandstone, siltstone, marlstone, andesite and chalk limestone gravel deposits. Dissolved oxygen (ranged from 4.2-6.35 mgL^{-1}) refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In limnology (the study of lakes), dissolved oxygen is an essential factor second only to water itself [42]. Consumption of $KMnO_4$ was ranged from 1.24-1.86 mgL^{-1} and that low values in all samples were found to be under recommended norms for drinking water. Concentrations of ammonia, nitrites, nitrates, sulfates, chlorides and fluorides in all samples were found to be under recommended WHO standards for drinking water.

Level assessment of metals in well waters

Chemical data from the Table 3 and World Health Organization standards for drinking water can be used for the assessment of water quality. From the results of AAS analyses, concentrations of 9 metals: Ca^{2+}, Mg^{2+}, Al^{3+}, Cu^{2+}, Fe^{2+}, Cr^{3+}, Zn^{2+}, Ni^{2+}, and Mn^{2+} in all samples were found to be under recommended WHO standards for drinking water and was found out that all well water samples fulfill the World Health Organization criteria set for drinking water. This indicates that well waters of this area have a "good status" and can be used for drinking water.

Basic statistical parameters (Mean, Geometric mean, Median, Minimum, Maximum, Variance and Standard deviation) for 20 parameters analyzed in 5 water samples are presented in Table 4. Based on the frequency histograms (Figure 3) and two dimensional scatter box plot diagrams (Figure 4) from experimantal data were constructed, and anomalous values (extremes and outliers) were registered (Table 4). In the sample station S_1 extreme values of HCO_3^- (341.6 mgL^{-1}) and Cl^- (25 mgL^{-1}) were registered and outlier values of pH (sample station S_1), manganese (sample station S_2), bromine (sample station S_3) and phosphates (sample station S_5) were registered as possible sign of geological influence in water of wells of Gollaku Mt.

The statistical regression analysis has been found a highly useful technique for the linear correlating between various water parameters. The correlation coefficient indicates positive and negative significant correlation of variables with each other. Positive correlation mean one parameter increase with other parameters and negative correlation mean one parameter increase with other parameters decrease. In study period, EC showed a high positive correlation relationship (Table 5) with pH, alkalinity, hardness, Cl^-, HCO_3^-, Mg^{2+}, Ca^{2+} and Mn^{2+}. pH showed a high positive correlation relationship with alkalinity, hardness, Cl^-, HCO_3^- and Ca^{2+}. Nitrate ions showed a high positive correlation relationship with PO_4^{3-}. Nitrite ions showed a high positive correlation relationship with Zn^{2+}. Phosphate ions showed a high positive correlation relationship with Zn^{2+}. Chlorides showed a high positive correlation relationship with alkalinity, hardness, HCO_3^- and Ca^{2+}.

Alkalinity showed a high positive correlation relationship with hardness, Mg^{2+} and Ca^{2+}. Total hardness showed a high positive correlation relationship with Mg^{2+} and Ca^{2+}. Acidity showed a high positive correlation relationship with Mg^{2+}. Dissolved oxygeny (DO) showed a high positive correlation with Br^- . Acidity showed a high positive correlation relationship with Mg^{2+}.

Results from Tables 2 and 3 are also compared with available results of three similar well waters in Kosovo (see Table 6). When concentrations of 16 selected measured parameters in well waters of Gollak Mt. are compared with similar well waters in Kosovo, following facts can be observed: EC, pH, total hardness and concentrations of HCO_3^-, NO_3^-, Cl^-, Mg^{2+}, Ca^{2+} well waters in Gollak Mt. were approximately the same with well waters of Mirosala. Consumption of $KMnO_4$ were significantly lower than well waters of Istog, Lipjan and Mirosala, and significantly higher than well waters of Lipjan. Concentrations of $Fe^{2+}$and Mn^{2+} of well waters in Gollak Mt. were lower than in well water of Istog. Finally, it can be summarized that water quality of well waters in Gollak Mt. were approximately the similarly with well waters of Mirosala used for comparison.

Table 6. Comparison of 16 parametrs in well waters of Gollak Mt. (this work) with concentrations in similar well waters in Kosovo

Parameter	Gollak well waters (min-max)	Istog well waters [43] (Mean)	Lipjan well waters [44] (Mean)	Mirosala well water [45] (Mean)
EC /µScm⁻¹	366-523	696.304	1029.1	475.5
pH /1	7.78-7.93	7.2	6.86	7.98
C. of $KMnO_4$ /mgL^{-1}	1.24-1.86	-	78.512	10.7133
Hardness /°d H	9.52-13.44	19.24	4.076	10.8283
Alkalinity /mgL^{-1}	29-40	39.96	20.74	-
HCO_3^- /mgL^{-1}	268-341.6	351.16	-	304.5833
NH_3 /mgL^{-1}	<0.0015	2.372	-	-
NO_2^- /mgL^{-1}	0.003-0.008	0.0617	-	0.0218
NO_3^- /mgL^{-1}	0.2-0.8	19.04	-	0.2133
Cl^- /mgL^{-1}	5-25	24.63	736.78	16.2593
PO_4^{3-} /mgL^{-1}	0.13-1.51	0.2927	-	-
Mg^{2+} /mgL^{-1}	19-23.2	33.37	3.56	24.375
Ca^{2+} /mgL^{-1}	43.68-54	85.313	23.72	39.4033
Fe^{2+} /mgL^{-1}	0.001-0.02	0.5287	-	16.858
Zn^{2+} /mgL^{-1}	0.022-0.047	0.0148	-	-
Mn^{2+} /mgL^{-1}	0.001-0.022	0.0223	-	-

CONCLUSIONS

Generally, well waters of Kosovo are enriched in dissolved solids, as the consequence of aquifer lithology and residence time of ground water. In this study the assessment of water quality and correlation coefficients between different pairs of variables of well water in the north eastern part of Prishtina were investigated. The statistical regression analysis shows that EC correlate high positively with pH, alkalinity, hardness, Cl^-, HCO_3^-, Mg^{2+}, Ca^{2+} and Mn^{2+}. pH showed a high positive correlation relationship with alkalinity, hardness, Cl^-, HCO_3^- and Ca^{2+}. In comparison with available results of three similar well waters in Kosovo, it can be summarized that water quality of well waters of Gollak Mt. were approximately the similarly with well waters of Mirosala. From the results of field work and laboratory analyses it was found out that well waters of Gollak Mt. are in high quality and fulfill the World Health Organization criteria set for drinking waters and can be used as high quality drink water.

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