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Some physical-chemical characteristics evaluation of bottled water versus municipal tap water available in Fogo Island (Cape Verde)

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Abstract

In recent years, a continuous demand for drinking water has been growing worldwide, thus demanding stricter quality control of this resource. The present study was designed to investigate the physical-chemical quality of tap water from two locations in Fogo island and two brands of bottled water. The investigated parameters were mainly: hydrogen potential (pH), electrical conductivity (EC), total dissolved solids (TDS), temperature (T), calcium (Ca), fluorine (F), iron (Fe), total hardness (CaCO3), aluminum (Al), sulfate (SO4) and magnesium (Mg). A higher concentration of minerals was observed in tap water samples. A sample of bottled water showed almost zero mineral content, and almost all analyzed parameters were following the parametric values established by Cape-Verdean Regulatory Decree and WHO standards. It is essential to analyze and understand the water label before purchasing any bottled water in order to know the mineral concentration and choose the water that is most appropriate considering individual food needs.

1. Introduction

Water is a natural resource conditioning by economic development and social well-being, whether as a drink or food, for hygiene, or as a source of energy and raw material [1]. Drinking water pollution has been a global challenge, that's why it deserves special attention since it is very impaired and seriously threatened by human activities. Freshwater is beneficial and indispensable resource for life, essential for domestic, industrial and agricultural activities [2]. The freshwater supply has increasingly become a limiting factor, and about 1 billion people are without safe drinking water worldwide [3].

Usually, drinking water can be polluted at the source, distribution line, or at the household level, and the polluted water is responsible for various waterborne diseases. according to WHO data about 80% of all illnesses and diseases worldwide are caused by waterborne and water-related diseases [4].

In Cape Verde, freshwater resources are extremely scarce. The scarcity of water resources that characterizes Cape Verde and the lack of capital for infrastructure investment, composed of the weak "affordability" by customers, have significant consequences in water sector development. The water supplied does not always meet the minimum quality standards for human consumption. During periods of high demand, there are often interruptions of water supply [5].

Recently, there has been a considerable worldwide increase in the consumption of bottled water due to consumer's awareness regarding bottled water as a healthy alternative to drinking water. However, bottled water is not necessarily safer than tap drinking water [6]. The reduced mineral intake due to the consumption of demineralized water is not automatically corrected by the diet [7]. Given the extensive consumption of bottled water, the question naturally arises of the long-term impact of waters of various chemical compositions on human health [8]. The present study aims to evaluate some physical-chemical characteristics of Cape Verde bottled water and the tap water consumed in Fogo Island.

2. Methodology

2.1 Sample collection

Four water samples were selected, two from public supply and two bottled from two different brands and identified numerically from 1 to 4, respectively. The physical-chemical parameters chosen for analysis were: hydrogen potential (pH), temperature (T), total dissolved solids (TDS), electrical conductivity (EC), calcium (Ca), magnesium (Mg), iron (Fe), fluorine (F), sulfate (SO4), total hardness (CaCO3) and aluminum (Al). The public water supply was collected at two different pumping stations in the Fogo Island, in order to be representative of the two locations. The public supply water from two different locations (samples 1 and 4) were of underground origin and do not undergo any type of treatment except the addition of chlorine. The bottled water was both from underground origin, however, one goes through the process of reverse osmosis (sample 2) and the other through the filtration process (sample 3). The samples of bottled water in Cape Verde (samples 2 and 3) were purchased from a local commercial establishment, close to the laboratory and were analyzed quickly, shortly after arrival, for chemical physical tests. At the pumping station, water was collected as follows: the tap was turned on, allowing the water to flow for 5 min to clean the stagnant water in the plumbing system. The tap was turned on again and then collected the samples with a slow stream of water. The pH, EC, T and TDS were measured in situ. They were duly identified and transported to the laboratory under appropriate conditions, a then analyzed the other parameters as soon as they arrived at the laboratory.

2.2 Sample analysis

The measurements of pH, temperature, electrical conductivity, and total dissolved solids were performed in a conductivity meter (HANNA instrument - HI9811-5). The determination of calcium, fluorine, aluminum, iron, magnesium, and sulfate was measured using Multiparameter Photometer (HANNA instrument - HI83399).

The determination of the total hardness was estimated using the titrimetric method with EDTA [9]. Firstly, 50 mL of water sample added 2 mL of pH 10 buffer solution in it and added 2-3 drops of Eriochrome Black T indicator. Then titrated with standard 0.01 M EDTA solution (with continuous stirring) until the last reddish colour disappeared. At the end point the solution turns blue. Total hardness was calculated as follow:

$$Hardness\ (mg/L\ as\ CaCO_3) = (V \times N \times 50 \times 1000) / (SV)$$

Where: V = volume of titrant (mL); N = normality of EDTA; 50 = equivalent weight of $CaCO_3$; SV = sample volume (mL).

2.3 Statistical analysis

The experiments were performed in triplicate. The results were expressed in means ± standard deviation (SD). The statistical analysis was performed using Microsoft Excel 2010 software, where the results were subjected to analysis of variance (ANOVA). Pearson's correlation coefficient was performed to determine the correlation between physical-chemical parameters.

3. Results and Discussion

3.1 Physical parameters

pH

The pH values varied from 6.8 to 8.2 (Table 1). At pH values lower than 6.5, water is corrosive and dissolves plumbing components. High values of pH (≥ 8.5) can promote hardness scale precipitation and make chlorine disinfectants more effective [10]. The pH was in accordance with the values established by Regulatory Decree [1] and WHO [11], and these values will not cause any harmful effect to consumers. pH lower than the range stipulated by the legislation were also found by other authors [1&12]. pH values similar to this study (7.42 - 8.31) was found in the study of physicochemical and microbiological quality of different brands of bottled in Lesotho [13] and (7.5 – 8.1) found in the study of physico-chemical characteristics of water samples in households of Bangalore city [14].

Temperature

The temperature ranged from 20.70 ºC to 25.75 ºC (Table 1). The bottled water presented lower values for temperature than tap water, and sample 1 exceeded the parametric values established by the Regulatory Decree [1] and WHO [11], but this may be related to the collection time.

Table 1: Result of physical parameters and parametric values.

Samples	**Parameters**			
	pH	EC (µs/cm)	TDS (ppm)	T (° C)
1	7.5	220	100	25.75 ± 0.75
2	6.8	10	0	20.67 ± 1.40
3	7.2 ± 0.087	110	40	23.00 ± 0.52
4	8.2 ± 0.22	325	155	24.77 ± 1.96
PV	6.5-9.5	2000	----	25
WHO	6.5-8.5	400	1000	25

Note: **PV** - Parametric values established by Regulatory decree nº 5/2017, Series I - Official Bulletin nº 63 from Republic of Cape Verde, November 6th, 2017. **WHO** - World Health Organization.

Different values of temperature (28.60 to 29.80ºC) was found in the study of the quality assessment of sachet and bottled bater in Nigeria and explained that could be due to high temperature during the period of the study [15]. Different temperatures can also be result of factors such as season of the year and period of the day. The temperature values higher than this study were obtained in the study of physical-chemical analysis of drinking water Quality in Cameroon [16].

EC and TDS

EC denotes the ability to conduct water. TDS consists of inorganic salts such as calcium, potassium, magnesium, sodium, bicarbonates, sulfates, chloride and small amounts of organic matter dissolved in water [17]. It is possible to verify in Table 1 that the bottled sample (sample 2) showed lower ionic concentrations 10 µs/cm, while the tap water (sample 4) presented a higher ionic concentration 325µs/cm. TDS values ranged from 0 to 155 ppm, and the higher TDS values were observed in tap water (samples 1 and 4). It should be noted that all water samples showed EC values lower than the parametric values established by Regulatory Decree [1] and WHO [11]. TDS presented values lower than that established by WHO, and the regulatory decree doesn't establish maximum limits for this parameter.

Satisfactory values for TDS (140.9 to 337.8 mg/L) and EC (341.4 to 675.6 μ/cm) were found in the chemical, microbial and physical evaluation of commercial bottled drinking water in Iran [18]. Some extremely low values of EC (2; 2; 5; 10; 14 μ/cm) and TDS (1; 2; 4; 7; 10 ppm) [17], showing that bottled water was deficient in essential minerals, as well as the sample 2 of the present study.

3.2 Chemical parameters

Total Hardness

Water hardness is not caused by a single substance but by various dissolved polyvalent metal ions, predominantly cations of calcium and magnesium. All samples (Table 2) showed total hardness values lower than that established by Regulatory Decree [1] and WHO [11]. Samples 1 and 4 can be classified as moderately hard since the values found are in the range of 60 to 120 mg/L $CaCO_3$, while samples 2 and 3 can be classified as soft water since the values found were less than 60 mg/L $CaCO_3$ [19]. Bottled water (samples 2 and 3) showed lower hardness compared to the tap water samples. The difference in hardness values may be related to the treatment process used by each bottled water company. Samples 1 and 3 used the disinfection process, sample 2 used reverse osmosis and sample 4 used filtration. Unlike other processes, such as reverse osmosis and distillation, the filtration process is less effective in removing dissolved solids [17]. This explains why the bottled water sample 3 higher hardness than the bottled sample 2. Hardness values lower the acceptable by the legislation were reported in the study of physicochemical and microbiological quality of bottled water with in Lesotho (1.87 to 32.27 mg/L) [13].

Table 2: Results of chemical parameters and Parametric Values.

Samples	Parameters						
	Ca (mg/L)	Mg (mg/L)	F (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Al (mg/L)	TH (mg/L)
1	37.3±0.81	5.2±0.75	0.05±0.12	5.2±0.75	0.005±0.01	0.05±0.02	70±1.23
2	<0.2*	<0.1*	0	<1*	0	0.001±0.003	0
3	7.6*	6.07*	0	<2*	0.007±0.02	0.001±0.003	23±3.98
4	38.3±2.58	8.2±1.2	0	13.2±0.98	0.245±0.17	0.01±0.01	72.3±0.33
PV	100	50	1.5	250	0.2	0.2	500
WHO	100	50	1.5	250	0.3	0.2	500

Note: *value of the label; **PV** - Parametric values established by Regulatory decree nº 5/2017, Series I - Official Bulletin nº 63 from Republic of Cape Verde, November 6th, 2017. **WHO** - World Health Organization.

Calcium and magnesium

Calcium and magnesium are prime elements in rocks and soil. The presence of a proper concentration of Ca and Mg in drinking water is important for health, especially for bones and teeth. Ca and Mg are strongly linked to a reduction in sudden death, and cardiovascular disease mortality [20].

Calcium (Table 2) ranged from 0 to 38.3 mg/L, with the highest value found in sample 4 and the lowest value in sample 2. All samples presented lower values than the parametric values established by Regulatory Decree [1] and WHO [11]. Varying values of calcium and magnesium, and some values of calcium were following the stipulated by the legislation (36; 39.5 mg/L Ca), some exceeded the maximum acceptable (56; 60; 76 mg/L Ca), and still, others presented values lower than the stipulated by the legislation (10; 15; 17 mg / L Ca). Some magnesium results were following the established by the legislation (24 mg/L Mg) and the others lower than the stipulated (2.5; 4; 7 mg/L Mg) in the study of water in Arabia [21]. Satisfactory values (28 to 78.5 mg/L Ca and 10.8 to 42.7 mg/L Mg) were found in the study of chemical and microbial quality of water in Iran [22] and some values of calcium and magnesium that exceeded the maximum limit acceptable by law (265; 268; 287 mg/L Ca and 103; 105; 335 mg/L Mg) were found in Romanian bottled drinking water [23].

Iron

Iron values (Table 2) ranged from 0 to 0.245 mg/L, with the lowest value found in sample 2 and the highest in sample 4. Samples 1, 2 and 3 showed iron values lower the maximum value established by Regulatory Decree [1] and sample 4 exceeded the maximum acceptable, however, all samples presented lower values than the maximum limit established by WHO [1]. Iron values lower than the maximum acceptable by law were mentioned by other authors [24-25]. Concentrations of Fe at high levels (2.25 to 3.20 mg/L Fe) were found drinking water available in Bangladesh and explained that this might be due to the processing methods and the origin of the water that guarantees the highest concentration of Fe [3]. Although the human organism needs up to 19 mg of iron per day, the potability standards require that a public water supply does not exceed the 0.3 mg/L, this limit being established due to aesthetic problems related to the presence of iron in water and the bad taste that iron gives it [26].

Aluminum and sulfate

The aluminum content (Table 2) ranged from 0.001 to 0.01 mg/L, with the highest value for the drinking water (sample 4) and the lowest value for the bottled water (samples 2 and 3). Lower values of sulfate were found in bottled water, where sample 2 showed lower than 1 mg/L and sample 3 lower than 2 mg/L, whereas for drinking water, sample 4 presented 13.2 mg/L and sample 1 showed 5.2 mg/L. The values of aluminum (Al) and sulfate (SO_4) in drinking water were higher than bottled water, however, all samples presented values following the parametric values established by Regulatory Decree [1] and WHO [11]. The present study corroborates others studies that they obtained acceptable levels of aluminum and sulfate [27-28]. Some aluminum values exceeded the maximum limit acceptable by law (0.55 to 0.8 mg/L Al) [29].

Fluorine

A moderate amount of fluoride (F^-) ions in drinking water contribute to good oral health. Fluoride concentration ranged from 0 to 0.05 mg/L, where only sample 1 showed value other higher than zero (0.05 mg/L). All samples presented values lower than those established by Regulatory Decree [1] and WHO [11]. Different studies presented some fluoride concentrations below the maximum allowed by law [30-31] and others showed values higher than the maximum limit acceptable by the legislation [25]. They affirm that the meteorization of minerals and rocks containing fluorine under the Earth's surface can be a fluoride source in natural waters. A value that exceeded the maximum acceptable by the legislation were found in drinking water in Arbaminch town, and explains that the highest value found (4.42 mg/L F) could be linked to the presence of fluoride compounds such as CaF_2, Na_3AlF_6 and Ca5 (PO4) 3F in groundwater [9].

In general, the physicochemical drinking water quality in Fogo island town was acceptable. According to all the findings from chemical and physical parameters, the values found in this study have no adverse effect to human health since the results were in accordance with the values stablished by the WHO. However, there may be adverse effects on human health in a long-term. When we drink very soft water we excrete large amounts of calcium, magnesium and other minerals in the urine, and the greater the mineral loss, the greater the risk of osteoporosis, osteoarthritis, hypothyroidism, coronary artery disease, hypertension and a long list of degenerative diseases usually associated with premature aging [32].

3.3 *Pearson's Correlation*

Karl Pearson's correlation coefficient (Table 3) was performed to determine the correlation between all physical-chemical parameters. The correlation can be perfect ($r = 1$), strong ($1 > r \geq 0.75$), moderate ($0.75 > r \geq 0.5$), weak ($0.5 > r > 0$) and non-existent ($r = 0$). Parameters as pH, EC, TDS showed a strong correlation with almost all other parameters with except for the aluminum and fluorine parameters. Temperature also showed a strong correlation with calcium ($r = 0.9373$), magnesium ($r = 0.7777$), aluminum ($r = 0.7599$) and total hardness ($r = 0.9624$). The total hardness also showed a strong correlation with calcium ($r = 0.9936$) and magnesium ($r = 0.7821$), but this was already expected. The hardness is caused predominantly by cations of calcium and magnesium.
Calcium and magnesium also showed a strong correlation with each other and with sulfate. In addition to the strong correlations mentioned above, sulfate also showed a strong correlation with iron ($r = 0.9494$) and total hardness ($r = 0.8101$). When the correlation is strong, it implies that the degree of affinity between these variables is quite significant. It follows, therefore, that for the sampled waters, these parameters originate from a common source.

Table 3: Correlation matrix for quality parameters of drinking water and bottled water.

	pH	*EC*	*TDS*	*T*	*Ca*	*Mg*	*F*	*SO_4*	*Fe*	*Al*	*DT*
pH	1										
EC	**0.9830**	1									
TDS	**0.9842**	**0.9980**	1								
T	**0.7674**	**0.8698**	**0.8525**	1							
Ca	**0.8727**	**0.9421**	**0.9454**	**0.9373**	1						
Mg	**0.8732**	**0.8722**	**0.8429**	**0.7774**	**0.7160**	1					
F	0.0846	0.2631	0.2574	**0.6583**	**0.5536**	0.0597	1				
SO_4	**0.9734**	**0.9318**	**0.9464**	**0.6381**	**0.8175**	**0.7513**	-0.0181	1			
Fe	**0.8830**	**0.7870**	**0.8054**	0.3802	**0.5954**	**0.6603**	-0.3277	**0.9494**	1		
Al	0.2569	0.4250	0.4229	**0.7599**	**0.6930**	0.1861	**0.9834**	0.1631	-0.1509	1	
DT	**0.8864**	**0.9557**	**0.9522**	**0.9624**	**0.9936**	**0.7821**	**0.5354**	**0.8101**	**0.5889**	**0.6721**	1

Correlation coefficients that is larger than 0.50 are indicated in bold.

Conclusion

Water quality and suitability are a significant concern due to various waterborne diseases and harmful impacts on human health. The results revealed that most of the physical-chemical parameters showed values following the parametric values established by the Regulatory Decree and WHO standard. Tap water presented higher mineral content comparing to bottled water. Bottled water (sample 2), essential minerals such as magnesium, calcium, and other minerals were practically nil. Although bottled water is designed as a safer alternative than drinking water, many brands go through a treatment process that leaves them with very low essential mineral content. Future studies should investigate the microbiological quality of those waters.

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