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RESEARCH ARTICLE

PHYSICAL AND CHEMICAL CHARACTERISTICS OF DRINKING WATER IN THE AREA OF HERZEGOVINA-NERETVA CANTON

Josipa Karačić[1,*], Stipe Čelan [2] and Zora Pilić[3]

[1] Faculty of Health Studies, University of Mostar, 88000 Mostar, BiH; [2]Institute for Food and Veterinary Medicine of Canton 10, Obtnička bb- Livno 80101; [3]Faculty of Natural Sciences, Mathematics and Educational Sciences, University of Mostar, Ulica Matice hrvatske bb- Mostar 88 000

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Corresponding Author:
Josipa Karačić

ABSTRACT

Introduction: The health suitability of drinking water is one of the basic measures to protect human health. Water analysis is the determination of organoleptic, physico-chemical, microbiological and other properties of water, in order to determine its health suitability. ***Methods*:** The aim of the work is to examine the physical and chemical characteristics of drinking water in the Herzegovina-Neretva canton using the standard methods prescribed by the Ordinance on health safety of drinking water and to determine the physical and chemical parameters. On the basis of the obtained physical and chemical indicators, obtain a detailed description of the state of water in the area of that canton. In the research, samples were taken from the area of Herzegovina-Neretva canton, sources are Dunajac (Čitluk Municipality), Neretva (Čitluk Municipality) and Radobolja (City of Mostar), which form the basis of the water supply of the aforementioned canton. The physical and chemical testing of water samples was carried out in the period from April 12 to 21, 2021. Water sampling was carried out according to the instructions prescribed by the Ordinance on health safety of drinking water. In the laboratory of the Faculty of Medicine of the University of Mostar, we performed the following procedures: measurement of pH values and electrical conductivity; procedures necessary for the determination of dry matter in samples such as filtration, drying, weighing and others; in order to determine the alkalinity of the water, the chloride in the water and the total hardness of the water, we carried out certain titrations; we also performed the necessary procedures to determine the consumption of potassium permanganate in the samples. The results of the sample analyzes were processed and presented in a table. ***Results:*** It can be seen that all the tested parameters were within the maximum allowed values, prescribed by the Ordinance on health safety of drinking water. ***Conclusion:*** According to the obtained results of the physical and chemical analyzes of the waters of the mentioned sources, we can conclude that the water in the area of Herzegovina-Neretva canton is safe and suitable for human consumption.

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INTRODUCTION

Water has always been a sign of life for man, it is a part of us and not a single living being can live without it. Water is the main ingredient of all living things. It is the most common chemical compound in the human body, the percentage of water in the human body changes with age. For example, the percentage of water in a newborn's body is about 80%, in adulthood a person has 60 to 65%, and in old age 55%. All chemical reactions in cells take place in water. Because of this, death occurs faster from lack of water than from lack of food, thus a person can survive about 8 days without water (Dragobratović, 2018). Fresh water is a source necessary for all forms of human activity. From the fact that all forms of life and all human activities are more or less connected to water, the importance of the relationship to water and the meaning of the documents regulating this relationship clearly emerge. Life as we know it on Earth is unsustainable without water.

Fresh water is a natural and economic good, a living space for plants and animals, a foodstuff, a raw material, a source or transmitter of energy, a means that heats, cools, washes, cleans, dissolves and dilutes, a means for agricultural and industrial production, or in short, multifunctional resource and as such constitutes one of the most important components of the entire life on land (Glavač, 2001). Economic development and urbanization lead, on the one hand, to a large increase in the need for water, and on the other, to endangering water sources and the aquatic environment. Water can thus become a limiting factor in development, and a threat to human health and the sustainability of natural ecosystems. Therefore, it is especially important for every society to balance these relationships and design a policy and method of managing , exploiting and protecting water resources (Višekruna, 2017). In addition, various diseases are transmitted through water, which is why analyzes of water for human consumption are very important.

The aim of this paper is to examine the physical and chemical characteristics of drinking water in the Herzegovina-Neretva canton using the standard methods prescribed by the Ordinance on health safety of drinking water and to determine the physical and chemical parameters. On the basis of the obtained physical and chemical indicators, obtain a detailed description of the state of water in the area of that canton.

General properties of water: Water is a very unusual mineral, with physical and chemical properties that no other known substance has. It consists of two hydrogen atoms and one oxygen atom and has a molecular weight of 18. Pure water is an odourless and tasteless liquid. It is colourless in thin layers, and blue in thicker layers. Water in its liquid state behaves strangely. The density of water is highest at 4 °C, and it decreases with further cooling. We call this phenomenon a water anomaly. On table no. 1. is a representation of the density of water that changes with increasing temperature. The density of ice is even 8% lower than that of liquid water at 0°C. This explains the fact that ice floats on water. This unusual property of water enables life under water (Dragobratović, 2018).

Table 1 . Display of water density at different temperatures

Density of water at different temperatures		
aggregate state	temperature / °C	density / (g/cm ^{3})
solid (ice)	0	0.9170
liquid (water)	0	0.9987
liquid (water)	4	1.0000
liquid (water)	10	0.9997
liquid (water)	25	0.9970
liquid (water)	100	0.9584

Water appears in nature in all three aggregate states: gaseous, liquid and solid. To transform water from one aggregate state to another, so-called latent heat is needed, which is added to or removed from the water. Latent heat is expressed in joules (J). The amount of heat required to increase the temperature of 1 gram of liquid water by 1 °C is 4.187 J, and is designated as specific heat (Filipović, 1987). Water in nature constantly circulates, it is a process in which water changes from one state to another. So, there are only about 11 million km^3 fresh water in the liquid state on Earth, a smaller part of that amount moves through the hydrological cycle (Mayer, 1996).

Water quality indicators: Water analysis consists of the determination of organoleptic, physico-chemical, microbiological and other properties of water, in order to determine its health suitability. Water quality is expressed by physical, chemical and biological indicators. Organoleptic properties are: colour, turbidity, smell and taste. Physico-chemical properties include the determination of the following parameters: temperature, hydrogen ion concentration (pH value), electrical conductivity, oxidizability, dry residue, total hardness, suspended substances, dissolved oxygen, free carbon dioxide, hydrogen sulfide and free residual chlorine (Masaru, 2005).

Legislation: All indicators of the quality of drinking water must be within the legally prescribed limits (MDK). TheOrdinance on health safety of drinking water (Official Gazette of Bosnia and Herzegovina, No. 40/10, 43/10, 30/12) prescribes the requirements and standards that drinking water must meet, the maximum permissible values of health parameters, methods of laboratory tests, and measures to monitor the health of drinking water. The aim of this Ordinance is to protect people's health from the negative impact of any pollution of water intended for drinking, by ensuring its health suitability (8. Official Gazette of Bosnia and Herzegovina). Water management criteria and priorities are established at the national level (Official newspaper, 1998). The area of water is legally regulated by the Water Act (Official Gazette of FBiH). Some of the goals of water management are as follows: preserving the good state of water in order to protect the life and health of people, to protect their property, to protect water and water-dependent ecosystems (Breţanski, 2010).

MATERIALS AND METHODS

The research will examine and determine the physico-chemical parameters of drinking water quality in the area of Herzegovina-Neretva canton. On the basis of 6 samples, sampled from three sources, 2 times each within a time period of half a year (periodically). The springs are Dunajac (Čitluk Municipality), Radobolja (Mostar Municipality), Neretva (Čitluk Municipality). The obtained results of the research can serve the mentioned municipalities that use drinking water from the mentioned sources, as well as the canton for insight and the state of drinking water quality in that area. The examination of colour, smell and taste is determined by human senses and compared with known smells and tastes.

Determination of the pH value of water: The pH value is defined as the negative logarithm of the concentration of hydrogen ions (Horvat, 2013). The instrument for determining pH is called a pH-meter (Savić, 1990). Procedure: before measuring, the electrode must be calibrated against a buffer of known pH value (Pilić, 2013). Before measuring, the electrode must be rinsed with distilled water and then with the sample. The electrode is immersed vertically into the sample, so that it is completely immersed in the sample. The measurement is performed in a sample that is at rest to avoid the loss of carbon dioxide. At the end of the measurement, the electrode must be rinsed with distilled water and stored in the reference electrolyte (Mijačević, 2016).

Determination of electrical conductivity: Electrical conductivity (κ) is the reciprocal of electrical resistance (κ = 1/ρ) and is expressed in S/m (Siemens per meter) or more commonly S/cm. The instrument for measuring electrical conductivity is called a conductometer (Pilić, 2013). The conductometer works in such a way that the electric current is transmitted through the solution by ions; positive ions move towards the negative electrode, and negative ions towards the positive electrode. Electrodes are most often made of platinum or a platinum alloy. Before use, the conductometer is calibrated using a standard solution (Mijačević, 2016). Procedure: Determination of electrical conductivity is carried out by immersing the electrode in a water sample and reading the obtained value on the scale of the instrument. For precise determination, the measurement is carried out when the sample and the measuring electrode have a temperature of 25.0°C + 0.1°C. The result is expressed as mS/m or µS/cm (Pilić, 2013).

***Determination of suspended substances**:* The dry residue is determined by evaporating 100 cm ^{3} of water on a water bath in a weighed platinum or quartz vessel. The rest is dried in an oven at 105°C to a constant mass. If a small residue is expected, a larger amount of water can be taken. The result is expressed in mg/dm ^{3} (16). The procedure is carried out by first drying the filter paper for an hour in an oven at 105 ^{0} C, and then weighing it, after which 100 mL of the water sample is filtered through a Buchner funnel. After that, the filter paper is dried again at 105°C in an oven for 1 hour. After that, the filter paper is weighed again, the difference in the weight of the filter paper before and after filtration gives the amount of suspended matter present in the water (Pilić, 2013).

Account:

$$\mathrm{mg}_{\mathrm{susp.tvari}} = \mathrm{mg}_{\mathrm{fiter+susp.tvari}} - \mathrm{mg}_{\mathrm{filtepapira}}$$

suspended matter, filter paper, sample

$$mg/L_{\mathrm{susp.\ tvari}} = \frac{mg_{\mathrm{susp.tvari}} \cdot 1000}{V_{\mathrm{uzorka}}\ (mL)}$$

suspendirana tvar, filtar papir,uzorak

Determination of water alkalinity: Alkalinity (basicity) of water consists of hydroxides, carbonates and bicarbonates (hydrogen carbonates) of alkaline and alkaline earth metals, mainly sodium, calcium and magnesium. Alkalinity is determined by water titration, hydrochloric acid solution or sulfuric acid solution with phenolphthalein and methyl orange indicators. Total alkalinity (T alkalinity) consists of alkalinity according to phenolphthalein and alkalinity according to methyl orange. Procedure: total (T) alkalinity is determined by titrating 100.0 mL of water, sulfuric acid solution, concentration (0.05 mol/L) or hydrochloric acid solution (0.10 mol/L), with phenolphthalein and methyl orange indicators.

For samples with an initial pH>8.3, the titration is performed in two stages:

- With the phenolphthalein indicator, until the indicator is discolored (p alkalinity);
- With methyl orange indicator, until the color of the indicator changes from yellow to orange (m alkalinity);

For samples with an initial pH<8.3, the titration is performed in only one step, only m alkalinity is determined. The ratio of hydroxides, carbonates and hydrogen carbonates depending on specific values is shown in table 2 (Pilić, 2014).

Table 2. Calculation of the amount of hydroxide, carbonate and hydrogen carbonate from the p and m value

Titration results	Hydroxides	Carbonates	Hydrogen carbonates
$p = 0$	0	0	m
$p < m/2$	0	$2\,p.m$	$m - 2\,p$
$p = m/2$	0	$2\,p.m$	0
$p > m/2$	$2\,p.m$ _ _	$2\,(mp)$	0
$p = m$	m	0	0

Determination of chloride in water: Almost all waters in nature, as well as waste water, contain chloride ions in the form of NaCl, $CaCl_2$, $MgCl_2$ .Chlorides in neutral or weakly basic solutions (pH is from 6.5 to 9) are determined by Mohr's method (16). For the determination of chloride in water, Mohr's method was used, which prescribes that 200.0 mL of a water sample be transferred to an Erlenmeyer flask with a pipette, then 1 mL of a 5% $K_2CrO_{4\ \text{solution is added}}$and the sample is titrated with a silver nitrate solution (0.100 mol/dm ^{3}) until a reddish-brown colour appears (Pilić, 2014).

Account:

$$\text{mg}_{\text{Cl}^-} / \text{dm}^3 = \text{V}_{AgNO_3} \cdot c_{AgNO_3} \cdot \text{M(Cl)} \cdot \frac{1000}{\text{V}_{uzorka}}$$

Determination of total water hardness: Water hardness comes from dissolved salts of calcium (Ca $^{2+}$) and magnesium (Mg $^{2+}$). Water hardness is expressed as $CaCO_{3\ \text{content}}$ in mg/L of water or in degrees (Savić, 1990). Hardness is divided into total hardness, which consists of calcium and magnesium salts, and carbonate hardness, which consists of carbonates and hydrogen carbonates (Horvat, 2013). Procedure: Total hardness is determined by titration, 100 ml of water sample is transferred by pipette into a 500 ml Erlenmeyer flask, 2 ml of ammonium buffer solution (NH4Cl/NH3 pH 10), 4 drops of indicator solution or "on the tip of a knife" of powder indicator are added, and it is immediately titrated with a 0.01 M EDTA solution until the colour changes from wine red to blue (Horvat, 2013).

Determination of calcium: The amount of calcium in water can be determined by titration with EDTA with the indicator murexide-K or by titration with a solution of potassium permanganate, because it precipitates in the form of calcium oxalate. Procedure: 100 ml of water sample is pipetted into the flask, 1 ml of buffer solution (pH 12) and " on the tip of the knife" indicator are added. It is titrated with EDTA solution until the colour changes from red to purple. The titration is carried out 5 minutes after the addition of the buffer solution. The proportion of calcium is expressed in mg Cao/l (Pilić, 2014).

Determination of magnesium: The proportion of magnesium is determined by calculation, so that the proportion of calcium expressed in German degrees is subtracted from the total hardness, expressed in German degrees, and the difference is multiplied by 10 MgO/Ca0 = 7.19 (Pilić, 2013).

Consumption of potassium permanganate: The consumption of potassium permanganate under standard conditions of analysis is a measure of the content of organic substances in water (Knežević, 2017). Potassium permanganate is reduced in an acidic environment with some organic and inorganic substances, and the consumption of potassium permanganate can only be conditionally taken as a measure of the content of organic matter in water. Procedure: measure 100 mL of water sample for analysis, 5 mL of sulfuric acid 25% in a 300 mL Erlenmeyer flask and add several glass balls. Heat until boiling. Add 15.00 mL of 0.002 mol/L KMnO 4 from the burette to the boiling solution and continue heating for exactly 10 minutes. If there is still a pink colour in the hot solution, add 15.0 mL of 0.005 mol/L oxalic acid from the burette and continue heating until complete decolorization. The excess of oxalic acid is titrated with a 0.002 mol/L standard potassium permanganate solution until a light pink colour appears, which lasts for about 30 seconds. If the consumption of the permanganate solution during this titration is greater than 10 mL, a smaller sample volume should be taken, and if it is less than 3 mL should be used with a larger sample volume (Pilić, 2013).

Account:

$$mg\ \text{KMnO}_4/L = \left[\left(15 + V_{\text{KMnO}_4}\right) \cdot c_{\text{KMnO}_4} - \frac{2 \cdot 15 \cdot 0{,}005}{5}\right] \cdot 158{,}04 \cdot \frac{1000}{V_{\text{uzorka}}}$$

RESULTS

After collecting water samples from the springs of Dunajac, Neretva and Radobolja, physical and chemical tests were also carried out. The results of the conducted tests are presented in tables and compared with the maximum permissible concentrations (MDK) of theOrdinance on health safety of drinking water.

Table 3. The results of the physical indicators of water quality parameters of the source of the Neretva (Čitluk municipality)

Analyzed parameters	Unit	The result	MDK
Temperature	^{0}C	7.2	6.5-8.5
Colour	Beige	Beige	Beige
Smell	Beige	Beige	Beige
Flavour	Beige	Beige	Beige
Turbidity	0	0	4
El. conductance	S/cm at 20 ^{0}C	49.7	2500

Table 4 . The results of the physical indicators of the water quality parameters of the source of Radobolja (City of Mostar)

Analyzed parameters	Unit	The result	MDK
Temperature	^{0}C	7.5	6.5-8.5
Colour	Beige	Beige	Beige
Smell	Beige	Beige	Beige
Flavour	Beige	Beige	Beige
Turbidity	0	0	4
El. conductance	S/cm at 20 ^{0}C	40.2	2500

Table 5 . Results of physical parameters of water quality indicators of the Dunajac source (Čitluk)

Analyzed parameters	Unit	The result	MDK
Temperature	^{0}C	7,8	6.5-8.5
Colour	Beige	Beige	Beige
Smell	Beige	Beige	Beige
Flavour	Beige	Beige	Beige
Turbidity	0	0	4
El. conductance	S/cm at 20 ^{0}C	79.1	2500

Table 6. Results of chemical parameters of water quality indicators of the source of the Neretva (Čitluk municipality)

Analyzed parameters	Unit	the results	MDK
pH	pH unit	7.68	6.5-9.5
Suspended substances	mg/L	< 1 mg	-
Alkalinity	mg/L	278	-
Chlorides	mg/L	30	250
Total hardness	^{0}nj	31.0435	-
KMnO $_4$	mg/LO $_2$	2.6865	5
Residual chlorine	mg/L	0.41	0.5

Table 7. Results of chemical parameters of water quality indicators of the source of Radobolja (Mostar)

Analyzed parameters	Unit	the results	MDK
pH	pH unit	7.61	6.5-9.5
Suspended substances	mg/L	< 1 mg	-
Alkalinity	mg/L	231	-
Chlorides	mg/L	25.2	250
Total hardness	^{0}nj	28,33	-
KMnO $_4$	mg/LO $_2$	3,1608	5
Residual chlorine	mg/L	0.40	0.5

Table 8. Results of chemical parameters of water quality indicators of the Dunajac spring (Čitluk municipality)

Analyzed parameters	Unit	the results	MDK
pH	pH unit	7.68	6.5-9.5
Suspended substances	mg/L	< 1 mg	-
Alkalinity	mg/L	392	-
Chlorides	mg/L	17.5	250
Total hardness	^{0}nj	35.92	-
KMnO $_4$	mg/LO $_2$	0.6321	5
Residual chlorine	mg/L	0.45	0.5

DISCUSSION

The Ordinance on health safety of drinking water requires that water intended for human consumption must be colorless, odorless and tasteless. The examination of colour, smell and taste is determined by human senses and compared with known smells and tastes. The results of the physical parameters for the sources of Dunajac, Neretva and Radobolja can be found in tables 3 and 4. and 5. The conducted testing of water samples from the mentioned sources found that the water samples are colourless, odourless and tasteless and as such are suitable for human consumption. It was also determined that the temperatures of the mentioned sources were in the range of 7.2-7.8 ^{0} C. The obtained values of the temperature parameter were within the maximum allowed values and are of optimal quality for the consumer. Turbidity, which is normally the result of suspended and colloidal substances present in the water, was also not found in the waters of the mentioned sources. Electrical conductivity is a parameter that indicates the amount of total dissolved salts (ions) in water that conduct electricity well. The obtained tests determined that the values of the parameters of the tested water samples ranged from 40.2 to 79.1 S/cm at 20 ^{0} C, and are in accordance with the maximum permissible values prescribed by the Ordinance. Tests of samples of the mentioned springs revealed that the values related to the amount of suspended substances were less than 1 mg for all three tested samples, the low concentration of suspended substances indicates that the water is not loaded with them and that it is suitable for the consumer. The permissible pH value for drinking water is determined by the range of 6.5 to 9.5 pH units. The obtained tests determined that the values of the parameters of the tested samples ranged from 7.61 to 7.68 pH, and the listed results were within the range defined by the Ordinance. Water alkalinity is caused by hydroxides, carbonates and hydrogen carbonates present in the water. The obtained alkalinity values for the mentioned springs ranged from 231 to 392 mg/L. The total hardness of water is made up of all the calcium and magnesium salts present in the water. The values related to the total hardness of the water ranged from 28.33 ^{0} nj to 48.92 ^{0} nj, which classifies these waters as very hard.

The consumption of KMnO4 serves to obtain data on organic water pollution with substances that can be oxidized. The consumption of KMnO4 during the analyzes of the sources of Dunajac, Neretva and Radobolja ranged from 0.6321 mg/L to 3.1608 mg/L. The specified values are within the maximum permissible values prescribed by theOrdinance on health safety of drinking water. The results of testing the samples of the mentioned springs related to the chloride content in the water ranged from 17.5 mg/L to 30 mg/L. The maximum permissible value of this parameter is defined up to 250 mg/L, and the results of the mentioned tests are within the permissible limits. An increased concentration of chloride in water gives the water a salty taste, and can cause negative physiological reactions in the consumer. The test parameter related to residual chlorine was in the range of 0.40 to 0.45 mg/L, and the test parameters were obtained in accordance withOrdinance on health safety of drinking water, which defined the value of residual chlorine up to 0, 5 mg/L. Therefore, we can conclude that the obtained test parameters are in accordance with the Ordinance on health safety of drinking water, and the water is safe and suitable for human consumption (7). Detailed results can be found in tables 6.7. and 8. Testing of drinking water is carried out every day in the world. Two similar studies were conducted in the area of Livno Municipality (Bosnia and Herzegovina) and Bjelovar-Bilogora canton (Republic of Croatia) in the period of 2015-2016, and report results similar to the results of this research. Therefore, the physical and chemical parameters of the mentioned samples were also within the maximum permissible values, and the water as such was safe for human use. The research conducted in the Požega-Slavonia canton (Republic of Croatia) related to the determination of the chemical quality of drinking water in 2016, based on the comparison of two samples of water from Pavlovci and water from Babin vir, obtained equally satisfactory results in accordance with the maximum permissible values (Mijačević, 2016)

FINDINGS

Ensuring the healthiness of drinking water is one of the basic measures to protect people's health. If the water is not healthy, it can cause various diseases. Therefore, water quality is regularly monitored and tested. -TheOrdinance on health safety of drinking water (Official Gazette of Bosnia and Herzegovina, No. 40/10, 43/10, 30/12) prescribes the requirements and standards that drinking water must meet, the maximum permissible values of health parameters, methods of laboratory tests, and measures for monitoring the health suitability of drinking water. The aim of this Ordinance is to protect people's health from the negative impact of any pollution of water intended for drinking by ensuring its healthiness. - In this work, the waters that form the basis of the water supply of the Herzegovina-Neretva canton were examined, samples were taken from three springs: Dunajac (Čitluk Municipality), Neretva (Čitluk Municipality) and Radobolja (City of Mostar). -Based on the obtained results of the following test parameters; temperature, colour, smell, taste, turbidity, electrical conductivity, pH value, suspended substances, alkalinity, corrosion in water, total hardness of water, consumption of potassium permanganate and residual chlorine, we can conclude that all parameters are in accordance with Ordinance on health safety of drinking water, and water in the area of Herzegovina-Neretva canton is safe and suitable for human consumption

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