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Water Quality for Human Consumption from the Public Water Supply System †

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Abstract: Adequate, safe, and accessible water constitutes an essential resource for life and is an indispensable factor for the survival of humanity. In order to ensure uncontaminated water for water supplies, industry and agriculture, water quality is defined by microbiological, biological, chemical, and physical indicators. Water monitoring is regulated with the aim to protect human health from the adverse effects of polluted water by monitoring indicator parameters. For the purpose of proving drinking water safety, water sampling was performed at ten different locations, which are part of the water supply network of the town of Virovitica, in Croatia, and its surroundings. The results showed that all the analyzed parameters were in accordance with the ordinance, i.e., that the quality of water for human consumption was satisfactory.

Keywords: water quality; microbiological; biological; chemical and physical indicators; water supply network of the city of Virovitica

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1. Introduction

The problem of water supply affects millions of people worldwide and more than one hundred million people in Europe. Approximately 80% of fresh water in Europe (for drinking and other needs) originates from underground water and rivers, which is why these sources are particularly threatened by climate change, pollution, and overexploitation of water resources [1]. According to the report on water resources in the world, which was issued by United Nations Educational, Scientific and Cultural Organization, UNESCO (Paris, France) in 2003, among 188 countries, Croatia ranked highly, 5th in Europe and 42nd in the world. Croatia is one of the few countries that mostly provides healthy water through the public water supply system, to which 80% of the population is connected. The data show that in the last ten years, less than 10% of the tested samples were unhealthy in Croatia [2]. Water for human consumption must meet the parameters of conformity for water for human consumption as prescribed by the "Regulation on parameters of conformity, methods of analysis, monitoring and safety plans of water for human consumption and the way of keeping a register of legal entities that perform the activity of public water supply". Healthy water for human consumption is water that does not contain microorganisms, parasites and their developmental forms in numbers that represent a potential danger to human health; water that does not contain harmful substances in concentrations that themselves or together with other substances represent a potential danger to human health and water in which the health parameters do not exceed the values prescribed by the ordinance (Official Gazette 125/17) [2]. Water sampling was conducted in the city of Virovitica and surrounding settlements (Podgorje, Đurađ, Lozan and Špišić Bukovica) at different locations over a period of 2 days. The aim of this work was to examine the drinking water quality of the Virovitica water supply system, that is, to determine certain indicators of water quality and to determine whether they meet the standards prescribed by law.

2. Materials and Methods

2.1. Location

The town of Virovitica is located in a lowland area, surrounded by Bilogora, wide open to the north and the Drava valley and is the center of the Virovitica Podravina County. The city area consists of two relief units: the Bilogora part in the south with a pronounced step-type relief where the altitude reaches up to 250 m and the plain part in the north which is no higher than 115 m above sea level and represents a typical plain region. The drainage system of Virovitica was built as a mixed sewage system into which rainwater and wastewater are discharged. In the county, 70% of inhabitants are supplied from organized water supply systems, while the average supply in the Republic of Croatia is around 65% [3]. On the water supply network of the city of Virovitica and its surroundings, sampling of drinking water was carried out at 10 different locations (1 public water supply and 9 local water supply systems).

2.2. Methods

Determination of the water temperature was carried out with the thermometry method in accordance with the SM 2550 B standard [4]. The temperature of water for human consumption was measured during the sampling with an immersion thermometer or with a Hach HQ40d oximeter. To determine water turbidity, a turbidity-testing method in accordance with the HRN EN ISO 70271:2016 standard [5] was used, using a Hach 2100P turbidimeter. Potentiometry is a method used to determine the pH value, in accordance with the HRN ISO 10523:2009 standard [6]. It is based on the measurement of the potential difference of the electrochemical cell using a Mettler Toledo MP220 pH meter. To determine the concentration of iron in water samples, a spectrophotometric method with phenanthroline in accordance with the HRN ISO 6332:2001 standard was used with a HACH DR5000 spectrophotometer [7]. Ammonia concentration in water samples was determined spectrophotometrically with salicylate in accordance with HRN ISO 71501:1998 [8]. The method with 1 N HCl acid was used to determine the nitrate concentration in the samples in accordance with the standard SM 4500NO3B [9]. The nitrite concentration in the samples was determined with sulfanilic acid, in accordance with norm M 221/E [9]. The spectrophotometric method with 1-(2-pyridylazo)2-naphthol was used to determine the concentration of manganese in water samples. Chloride concentration in water samples was determined spectrometrically by the ferrocyanide method, in accordance with the SM 4500CL E standard [9]. Determination of potassium permanganate consumption was carried out using the permanganate index in accordance with the HRN EN ISO 8467:2001 standard [10]. To determine the electrical conductivity in water, a conductometric method was used, in accordance with the HRN EN 27888:2008 standard, using a Mettler Toledo MC226 conductometer [11]. Measurement of free (residual) chlorine was performed directly at the point of consumption in the water sample using the Pocket Colorimeter II colorimeter [2]. The total number of coliform bacteria and Escherichia coli in drinking water samples was determined by membrane filtration methods for water with low background bacterial flora according to HRN EN ISO 93081:2014 [12]. Determination of the number of enterococci in drinking water samples was conducted using a method of membrane filtration according to HRN EN ISO 78992:2000 [12]. The number of Pseudomonas aeruginosa in drinking water samples was determined by the method of membrane filtration according to HRN EN ISO 16 266:2008 [12].

3. Results and Discussion

According to the ordinance [12], the health parameters of water for human consumption (microbiological, chemical), indicators (chemical, microbiological) and parameters of radioactive substances are precisely prescribed. The ordinance specifies the parameters of groups A and B in the monitoring of water for human consumption. The purpose of monitoring water for human consumption on parameters of group A is to obtain basic data on the physical, chemical, and microbiological parameters of conformity of water for human consumption and data on the efficiency of processing water for human consumption, especially disinfection. In contrast to the monitoring of water for human consumption on the parameters of group A, the purpose of this is to obtain all the data on the parameters of the conformity check of water for human consumption, additionally with the parameters of radioactive substances. In the case of a deviation of the indicator parameter from the maximum-allowed concentration, it is necessary for an assessment of the impact of the parameter on human health to be carried out by a competent institute for public health and to take all necessary measures. In Tables 1 and 2, the physical and chemical indicators of the water samples are presented.

Table 1. Physical indicators of samples.

Samples	Temperature (°C)	pH Value	Turbidity (NTU)	Free Chlorine (mg Cl_2/L)	Conductivity (µS/cm)
VT-1	9.60	7.61	0.59	0.06	544
VT-2	11.30	7.65	0.36	0.01	518
VT-3	12.20	7.69	0.53	0.04	525
VT-4	9.10	7.74	0.53	0.06	513
VT-5	11.10	7.62	0.31	0.18	506
VT-6	7.90	7.54	0.52	0.09	519
VT-7	8.00	7.52	0.52	0.01	497
VT-8	9.60	7.44	0.76	0.08	503
VT-9	13.60	7.40	0.50	0.02	490
VT-10	9.40	7.55	0.36	0.11	514

Table 2. Chemical indicators of samples.

Samples	Ammonia (mg $NH_4{}^2$/L)	Iron (µg/L)	Manganese (µg/L)	Chlorides (mg/L)	Nitrites (mg $NO_2{}_-$/L)	Nitrates (mg$NO_3{}_-$/L)
VT-1	0.01	20.0	5.98	14.04	0.0	1.64
VT-2	0.01	1.0	8.64	14.35	0.0	1.73
VT-3	0.01	19.0	8.28	14.95	0.0	1.64
VT-4	0.01	9.0	9.37	14.86	0.0	1.73
VT-5	0.01	8.0	6.49	14.05	0.0	1.68
VT-6	0.01	14.0	5.17	13.19	0.0	1.64
VT-7	0.01	76.0	11.63	14.14	0.0	1.73
VT-8	0.01	38.0	9.06	14.86	0.0	1.64
VT-9	0.01	0.0	4.68	14.21	0.0	1.59
VT-10	0.01	6.0	6.27	16.01	0.0	1.51

The pH values of the studied samples were in the interval from 7.40 to 7.74. It can be concluded that all the pH values of the analyzed samples are within the limits prescribed by the ordinance, i.e., within the interval of pH values from 6.5 to 9.5 [12]. Water temperature is closely related to the temperature of the environment and depends on the temperature of the soil that surrounds it, the inflow of hot and cold underground water, and the season. The limit value for the drinking water temperature prescribed by the ordinance is 25 °C, while the most optimal is 15 °C. As can be seen from the results, the temperature values of all analyzed samples were below the limited value of 25 °C. If the temperatures are higher, some microorganisms may develop, while low temperatures slow down the flocculation and coagulation processes. Furthermore, water with lower temperature values contains little dissolved gas and has a bad taste. Free residual chlorine is excess chlorine after disinfection, and the free chlorine concentration was measured at the sampling site. The limit value for free chlorine concentration in drinking water is prescribed by the ordinance and is 0.5 mg Cl2/L. As can be seen from Table 1, all values were below the limit value. Turbidity can be determined in all water that does not contain large particles and coarse sediment that settles quickly. The highest turbidity value was obtained in sample VT-8 (0.76 NTU), while the lowest value was in sample VT-5 (0.31 NTU). Meteorological conditions can affect water turbidity, i.e., turbidity increases with the amount of precipitation [13]. Electrical conductivity is an indicator of the conduction of an electric current in a liquid, and it depends on the temperature of the water, the concentration of ions, the type of ions presents in the water, and the mobility of the ions. It is evident from the results that the values were in accordance with the ordinance, i.e., they were below the limit value (2500 μS/cm) [2]. In Table 2, the results of the chemical indicators of water quality are presented. Ammonia is an indicator of the possible presence of microorganisms, animal, and fecal waste, has a characteristic smell and is corrosive to certain materials. Characterization of the studied groundwater samples was carried out in the reductive conditions of the aquifer, where the concentration of free natural ammonia is relatively high [13]. The results of ammonia concentrations in the samples were below the value of the calibration curve, i.e., a negative value, and it can be concluded that the concentration of ammonia in the samples was negligible or that ammonia was not present in the samples at all.

Characterization of the studied samples was carried out to find any elevated contents of dissolved iron, manganese, fossil ammonia and accompanying constituents [13]. An increase in the concentration of iron in water can occur when the pH value and water temperature increase causing changes in the color and smell of the water [14]. The values of iron concentration in the analyzed samples were below the limit value determined by the ordinance (200 μg/L) [2]. Manganese (Mn) is an essential element for the human body in small quantities, and its deficiency manifests itself in slowed growth and development and shortens life span because it participates in the reproductive processes. Comparing the results of the Mn concentration with the limit value of 50 μg/L, it was evident that all values were in accordance with the ordinance [2]. An increased concentration of Mn, as well as iron, occurs due to an increase in the temperature and pH value of the water [15]. Natural water contains a certain concentration of chlorides, and the most common forms are NaCl, $CaCl_2$ and $MgCl_2$. Most drinking water contains 10 to 30 mg of chloride per liter of water, while water with more than 250 mg/L of chlorine in the form of chloride has a salty taste and is not recommended for drinking. High concentrations of chloride in water can occur due to changes in the pH value of water and can affect the development of corrosion in distribution systems [16]. From the results shown in Table 2, it is evident that all the values of the analyzed samples were below the limit value (250 mg/L). Nitrites occur naturally as part of the nitrogen cycle, and in water can be evidence of fresh fecal pollution. They can be found in wastewater, storm sewers of cities and agricultural areas. Table 2 shows that the measured nitrite concentrations in the analyzed samples were 0.0 mg NO_{2-}/L, that is, nitrites were not present in the samples. Increased concentrations of nitrates in water can occur in places where fertilizers are used, during the rotting of plant and animal remains, in industrial waste and wastewater from sludge landfills. The measured values of nitrate concentrations in the analyzed samples are shown in Table 2. The highest values were obtained in samples VT-2, VT-4 and VT-7 (1.73 mg NO_{3-}/L), while the lowest value was obtained in sample VT-10 (1.51 mg NO_{3-}/L), but all values were below the limit value which is 50 mg NO_{3-}/L. The most important representatives of fecal coliform bacteria are Escherichia coli and fecal streptococci (enterococci). The key factors for the growth and reproduction of Escherichia coli in water are the water temperature and the increased amount of nutrients and organic substances in the water [17]. In all studied samples, Escherichia coli as well as Enterococcus were not present, that is, all values were 0 cfu/100 mL. Enterococci are the most suitable group of bacteria for assessing the hygienic quality of water because their numbers correlate with the presence of numerous pathogenic bacteria, total coliform bacteria, and enteroviruses. The presence of enterococci is an indicator of fecal contamination. Increased water temperature and nutrients and organic substances promote the development and reproduction of enterococci in water. The presence of Pseudomonas aeruginosa is related to openings in the water supply system (e.g., taps). Increased water temperature, changes in pH value, nutrients and organic substances in the water and a failure to maintain the distribution system encourage the development and reproduction of Pseudomonas aeruginosa. If the analysis results are in the range of 110 cfu/100 mL, it is necessary to assess the risk of using such water. Pseudomonas aeruginosa was not detected in the analyzed samples.

4. Conclusions

Water quality indicators are determined by different methods, and the determination of indicators is of significant importance for the prevention of water pollution that is used for water supply, agriculture, industrial processes, and leisure. The analyzed samples of water for human consumption of the water supply system of Virovitica and its surroundings, based on microbiological, physical and chemical indicators of the quality of drinking water, comply with the ordinance on conformity parameters, methods of analysis, monitoring and safety plans for water for human consumption and the way of keeping a register of legal entities that perform the activity of public water supply. According to estimates by the World Health Organization, approximately 1.2 billion people fall ill due to contaminated water. Today, according to estimates by the international organization of the United Nations, 1.5 billion people do not have safe drinking water, and in the next 25 years that number will grow to about 4.5 billion. Water is not a commercial product, but a heritage; therefore, it is necessary to make individuals aware of controlled waste disposal, rational water consumption, wastewater treatment, controlled application of agrotechnical substances (pesticides), monitoring the transport of dangerous substances and, ultimately, water conservation and protection.

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