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Measurement of water quality parameters using the spectrophotometry method

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Abstract: Having quality drinking water is a leading factor in maintaining public health, environment protection, and the promotion of sustainable development in industrial and agricultural needs. Measurement and analysis of chemical parameters in drinking water are crucial for ensuring the safety and quality of water for public health. This research was conducted using the spectrophotometry method including a UV-VIS DR 6000 HACH Lange spectrophotometer with a wavelength range of 190 to 1100 nm and a high-speed temperature thermostat HT 200 S. Chemical parameters that are measured in this research are chlorides, nitrates, nitrites, potassium, phosphates, and ammonium. All of them are measured on a different wavelength. Samples were taken from three measuring points, all of which are used as drinking water sources and irrigation in the nearby villages. One measuring point is a thermal spring and the other two springs from the foot of a mountain. The water from all three water sources is considerable drinking water. One sample is taken from Vardar River and its water is considered as non-drinking. The results of all measured parameters will be represented through a table and bar graphic chart.

Keywords: water quality parameters, water quality analysis, drinking water, spectrophotometry, DR6000.

1. Introduction

Water quality is a crucial aspect of the well-being of both ecosystems and human populations. It is important to accurately measure and monitor water quality parameters to understand the health of aquatic systems and ensure safe drinking water [1].

There are traditional analytical methods for water quality monitoring that can be expensive, time-consuming, and require specialized laboratory conditions and equipment, making the measurement inconvenient and unsuitable. In contrast, ultraviolet/visual spectrometry (UV/Vis) offers significant benefits due to its accessibility and affordability. This makes UV/Vis a more practical option for water quality monitoring [2]. According to the needs and water properties, there are also available UV, Vis, or UV-Vis measurement technology. UV-Vis spectroscopy works by measuring how pollutant molecules in water absorb light at specific wavelengths, causing electron transitions from the ground state to an excited state and reducing transmitted light. This method relies on the Lambert-Beer law, which establishes a strong correlation between the absorption spectrum and the concentration of the substance, allowing for the detection of water pollutants [3]. Usually, UV-Vis is the most popular technique since it offers a wider area of wavelength. Also, UV-Vis spectrometry is suitable for multi-parameter monitoring, classifying water quality, and setting up quality alarms [4]. In [5] is represented by the usage of UV-Vis spectrophotometry for detecting possible pollution while producing NaCl because it also can detect metal ions, organic pollutants, chemical oxygen demand (COD), and many other parameters. Measurement of total sulfate (SO4) and nitrate (NO3) is done by using the UV-Vis spectrophotometry method [6]. Despite the water parameters, the UV-Vis spectrophotometry method can be applied in the determination of bacteria in the water samples, for example, cyanobacteria and hexavalent chromium which is very poisonous and can cause severe illness. According to [7], despite the measurement, the results from the VU-Vis are used to determine the water quality index (WQI) using artificial neural networks (ANN). Paper [8] aims to simplify the monitoring of the water used in agriculture by combining UV-Vis spectrometry using ANN with (convolution neural networks) CNN and partial least squares (PLS) to calculate water parameters.

The measured parameters in this paper are chloride, nitrate, calcium, nitrite, ammonium, phosphate, and COD and BOD. In this paper, measurements are done on water samples from two springs (currently used as drinking water), one thermal water spring (currently used as drinking water as well), and one river.

2. Measuring parameters

The purpose of this paper was to do water quality (WQ) measurements using spectrophotometry equipment. The samples that were collected were mostly from springs from the southern part of Macedonia, mainly in the Gevgelija region and the foot of Kozuf Mountain. Samples are taken from three different spring points, Smrdliva Voda (mountain spring), Konsko (mountain spring), Negorski Banji (thermal spring), and Vardar River. The water from all three springs is used as drinking water by the citizens of the country and the tourists. The test samples are taken directly from the spring where people often fill bottles of water and use it as drinking water. To ensure the water quality level (WQL), chlorides, nitrite, nitrate, calcium, phosphate, and ammonium have been taken into consideration for measuring the WQ.

2.1. Chlorides in the water

In drinking water, chloride levels are significant because they can affect water quality, taste, and corrosivity. The taste threshold for chloride (sodium, magnesium, and calcium salts) in the water is in the range of 200 up to 300 mg/L. Above that, the water taste is affected by getting a salty taste [9]. High levels of chloride, especially when combined with high levels of sulfate, can cause corrosion in plumbing systems like copper, lead, and iron. This corrosion can damage pipes and appliances and increase metal levels in the water, posing a health risk. While chloride itself is not toxic and is an essential nutrient, very high levels may signal pollution or contamination from industrial waste or agricultural runoff, which could introduce other harmful substances into the water supply [10]. Low chloride levels typically indicate good water quality, suggesting the absence of pollution from sources like industrial waste or agricultural runoff. This is common in freshwater and spring water with minimal contamination. Water with low chloride levels is less likely to taste salty, does not contribute to corrosion in plumbing, and is generally preferred by consumers for drinking and cooking.

2.2. Nitrate and nitrite in the water

According to the EU Drinking Water Directive (202/2184), there are parametric limits for nitrite and nitrate in drinking water. World Health Organization (WHO) guidelines value for nitrate is a maximum of 3 mg/L for drinking water, but the best-measured value for the nitrite is 0.50 mg/L for drinking water and 0.10 mg/L for water after chemical treatment. The same directive, the EU Drinking Water Directive (202/2184), provides information about the nitrate in the water which is 50 mg/L according to the WHO guidelines for the drinking water [11]. High nitrate levels often result from agricultural runoff, industrial discharges, and fertilizers. These sources introduce excessive amounts of nitrates into the water supply, indicating potential contamination and poor water quality. In terms of health risks, increased levels of nitrates in drinking water can pose serious health risks, especially to infants and pregnant women. One significant risk is methemoglobinemia where nitrates interfere with the blood's capacity to carry oxygen. For adults, long-term exposure to high levels of nitrates is associated with an increased risk of certain cancers and other health problems. A lower number of nitrates in drinking water represents the so-called ecological balance. Lower nitrate levels indicate a well-balanced ecosystem and minimal contamination from human activities. It indicates that water treatment processes effectively manage pollution and maintain water quality. For health safety reasons, drinking water with low nitrate levels is generally considered safe for all populations, including vulnerable groups such as infants and pregnant women. Minimizes the risk of methemoglobinemia and other nitrate-related health problems. [12][13]. Nitrites themselves are relatively harmless, but they can be rapidly transformed into nitrate, which is a concern because of the problems that can arise from human exposure above the above nitrate levels.

2.3. Potassium (calcium) in the water

Potassium is an essential nutrient that plays a key role in a variety of body functions, such as heart regulation, fluid balance, and nerve and muscle communication. In the context of drinking water, potassium levels are generally low and usually not a major concern for water quality or health. However, understanding the implications of high and low potassium levels in drinking water may be important in specific contexts. High levels of calcium in drinking water are relatively rare. When present, they may indicate contamination from natural sources, agricultural runoff (especially from fertilizers), or industrial processes. Low levels of calcium in drinking water are common and generally considered safe. Calcium intake from water is typically a small component of total daily intake, with the majority coming from foods such as fruits, vegetables, meat, and dairy products. There are no direct health risks associated with low potassium levels in drinking water. The average concentration of potassium in drinking water is approximately 10 mg/L, and normal concentration is considered 2.5 mg/L. A large concentration in drinking water is considered 3000 mg. Springs usually have a lower concentration of potassium in mg/L which is proved according to the measurement in Table 1 and the measurements represented in [14].

2.4. Phosphate in the water

Normally, naturally occurring phosphate levels in drinking water are low. Low levels may not pose a direct health risk, but phosphates are essential nutrients for plant growth. Thus, if water with low phosphate levels is used for irrigation, it may not provide enough nutrients for optimal plant growth. High levels of phosphates in water can indicate contamination from sources such as fertilizers, sewage, or detergents. While phosphates themselves are not typically harmful to humans in small amounts, their presence at elevated levels can lead to eutrophication in water bodies. Eutrophication can cause excessive growth of algae and other aquatic plants, depleting oxygen in the water and harming aquatic life. In drinking water, excessive levels of phosphates can cause problems in the water treatment process, and although not directly harmful, they can indicate the presence of other contaminants that can be harmful [15].

2.5. Ammonium in the water

Ammonia and its ionized form, ammonium, are naturally occurring organic compounds produced during the decomposition of proteins, manure, urine, and other nitrogen-containing substances. Ammonia gas is commonly found in areas with large numbers of confined animals, chickens, or birds, and it causes a sharp odor associated with soiled diapers. Some drinking water treatment processes add small amounts of ammonia, typically less than 0.4 mg/l (ppm), to enhance chlorine's disinfecting ability. Ammonia is rarely present in unpolluted surface or well water, but contaminated water with sewage, animal waste, or fertilizer runoff may have elevated levels. The US Environmental Protection Agency (USEPA) has not set a maximum contaminant level (MCL) for ammonia in drinking water. Environmental limits for ammonia in US surface water range from 0.25 to 32.5 mg/l (ppm). The National Academy of Science recommends, and many European countries have adopted, a drinking water standard of 0.5 mg/l (ppm) [16].

This paper together with [17] indicates and opens a path to using the measurements for developing a machine-learning model that can predict the existence of some bacteria in the water.

3. Measurement process – Hardware

In this paper, UV-Vis spectrophotometry has been used to analyze the water samples. Besides the spectrophotometer, the thermostat for solution digestion has been used. A high-speed thermostat has been used because some of the reagents needed the solution to be digested before it is inserted in the spectrophotometer. Hardware equipment used for this research are HACH Lange DR 6000 spectrophotometer and High-speed temperature thermostat HT 200 S. Spectrophotometry as a method, quantifies the light absorption of a chemical substance by analyzing the intensity of light passing through a sample solution. It operates on the principle that each compound absorbs or transmits light within specific wavelength ranges, enabling the measurement of known chemical substances. Spectrophotometry in theory is based on Beer-Lambert Law [18], where equation 1 states that the absorption (A) of light by a substance in solution is directly proportional to its concentration (c) and the length of the light path (l) through the solution, provided the wavelength of the light and the molar absorptivity (ε) of the substance are constant.

$$A = \varepsilon \cdot l \cdot c \tag{2}$$

Figure 1 represents the UV-VIS HACH Lange DR 6000 spectrophotometer while Figure 2 represents the HT 200 S high-speed temperature thermostat, laboratory equipment used for measurement of the mentioned parameters.

Figure 14. HACH Lange DR 6000 spectrophotometer

Figure 15. HT 200 S high-speed thermostat

The measuring process was divided into five steps, taking a strictly defined amount of sample according to the requirements based on the measured parameter, putting the amount of the sample into the suitable LCK reagent, shaking the mixture in the LCK reagent, and if the measuring parameter and the reagent requires, it must be put into the high-speed thermostat so the reagent could be warmed in order the chemical to reach with the water sample. Then the LCK cuvette is put into the spectrophotometer. The measuring procedure is represented in Figures 4 to 9, and Figure 3 represents the measurement setup.

Figure 16. Measuring equipment with HACH Lange DR 6000 and HT 200 S

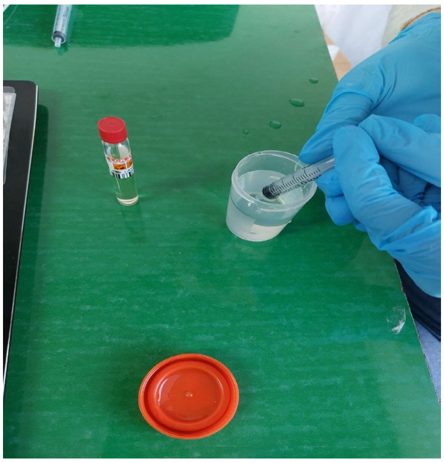

Figure 17. Taking a specific amount of sample

Figure 18. Putting the specific amount of sample into the LCK cuvette

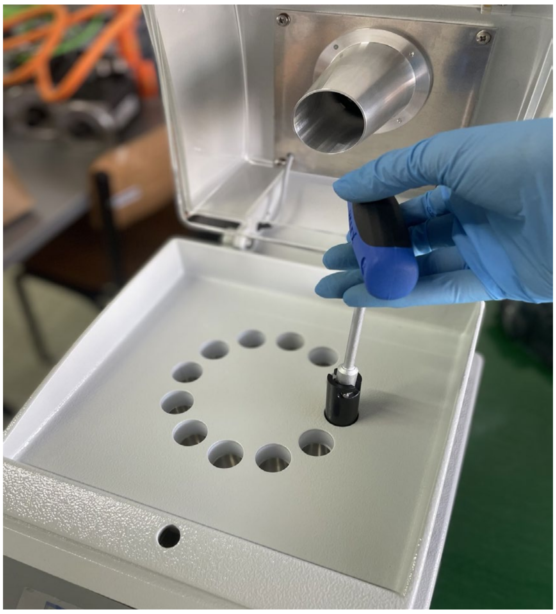

Figure 19. Preparing the high-speed HT 200 S thermometer

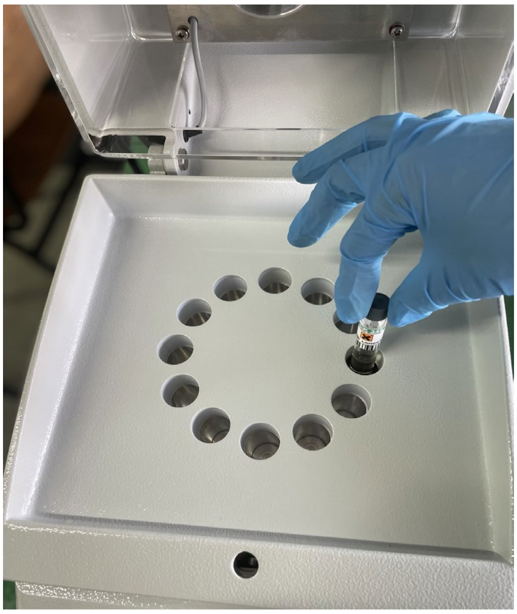

Figure 20. Putting the LCK cuvette inside the HT 200 S so the mixture can be warmed

Figure 21. Putting LCK cuvette into the HACH Lange DR 6000 spectrophotometer

Figure 22. Closing the lid, so the spectrophotometer can start measurement

4. Results and discussion

As represented above in this paper, chloride, nitrate, calcium, nitrite, ammonium, and phosphate were measured parameters to analyze the WQ from the spring that is used by the people living in the region as drinking water.

Measured results are represented in Table 1. It indicates that each measuring reagent has a specific measuring range. Based on the data, all parameters except for nitrites fall within the proposed range, and nitrites are the only parameters that are outside the proposed range.

Table 1. Measured water quality parameters

No.	Measuring parameter	Symbol	Reagent name	Smrdliva Voda (spring)	Konsko (spring)	Negorski Banji (thermal spring)	Vardar	Measured value	Measuring range
1	Chloride	Cl	LCK 311	3.47	3.30	1.11	1.27	mg/L	1-1000 mg/L
2	Nitrate	NO3^(-N)	LCK 339	0.070	0.269	0.098	1.51	mg/L	0.23-13.50 mg/L
3	Calcium/ Potassium	K+	LCK 328	11.4	10.8	19.2	11.5	mg/L	8-50 mg/L
4	Nitrite	NO2	LCK 541	-0.004	-0.004	-0.004	-0.004	mg/L	0.0015-0.03 mg/L
5	Ammonium	NH4	LCK 304	0.007	0.076	0.084	0.131	mg/L	0.015-2.0 mg/L
6	Phosphate	PO4	LCK 349	0.264	0.002	0.9	0.084	mg/L	0.05-1.50 mg/L

According to the results represented in Table 1, Figures 10 to 15 will represent the comparison between all four measuring points by the measuring parameters one by one.

Figure 10 represents the comparison between all four measuring points by the measuring parameter chloride. The lower concentration of chloride in all four water samples indicated that in the water, there were no discharges from the agricultural runoffs or any industrial waste. Also, the high concentration in Smrdliva Voda spring and Konsko spring is expected due to the corrosion presence on the pipes. The pipe corrosion is visible to the naked eye. The water in Smrdliva Voda also contains a lot of iron. Thermal spring Negorski Banji has a lot less concentration of chloride which also means that there is no corrosion on the supply pipeline which can be also seen with the naked eye. Measured values for all four measuring points are in the permitted area that is safe for human health when consuming this type of water.

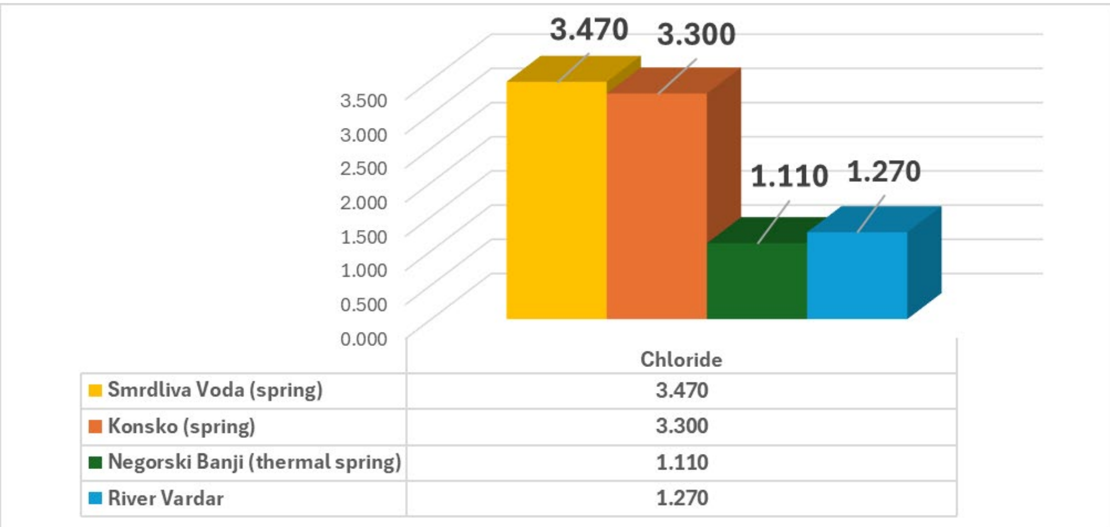

Figure 23. Comparison between the measuring points (springs and river) for chloride presence

Figure 11 represents the comparison between all four measuring points by the measuring parameter nitrate. According to the WHO directives, the maximum level of drinking water must not exceed 0.5 mg/L. The represented results show that the water from the Smrdliva Voda spring, Konsko spring, and Negorski Banji thermal spring have nitrate levels smaller than the maximum defined, 0.5 mg/L which indicates that from the nitrate point of view, it is safe water to be drunk. Also, the low level of nitrates indicates that there are now agricultural runoffs in the spring or any other waste discharge. According to the value of nitrate in River Vardar, could be concluded that that water is not suitable for drinking but also the small amount of nitrate indicates that there are no agriculture runoffs or any industry discharges with heavy metals.

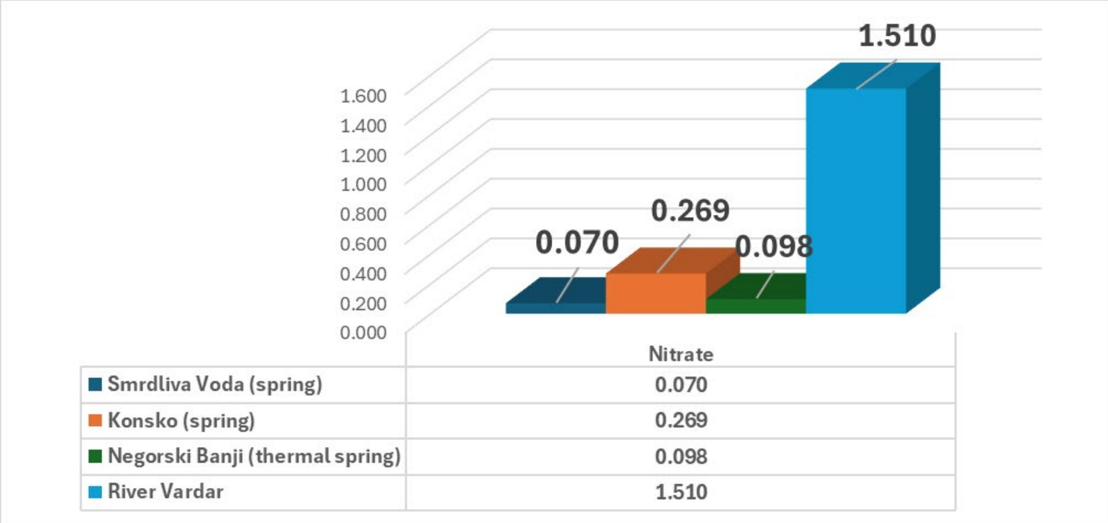

Figure 24. Comparison between the measuring points (springs and river) for nitrate presence

Figure 12 represents the nitrite level in all four measuring points. The results are negative and all the same. That could indicate that the reagent LCK 541 is damaged and cannot mix up with the water sample. However, according to the nitrate results it is expected the results for the nitrite to be similar to those of the nitrate.

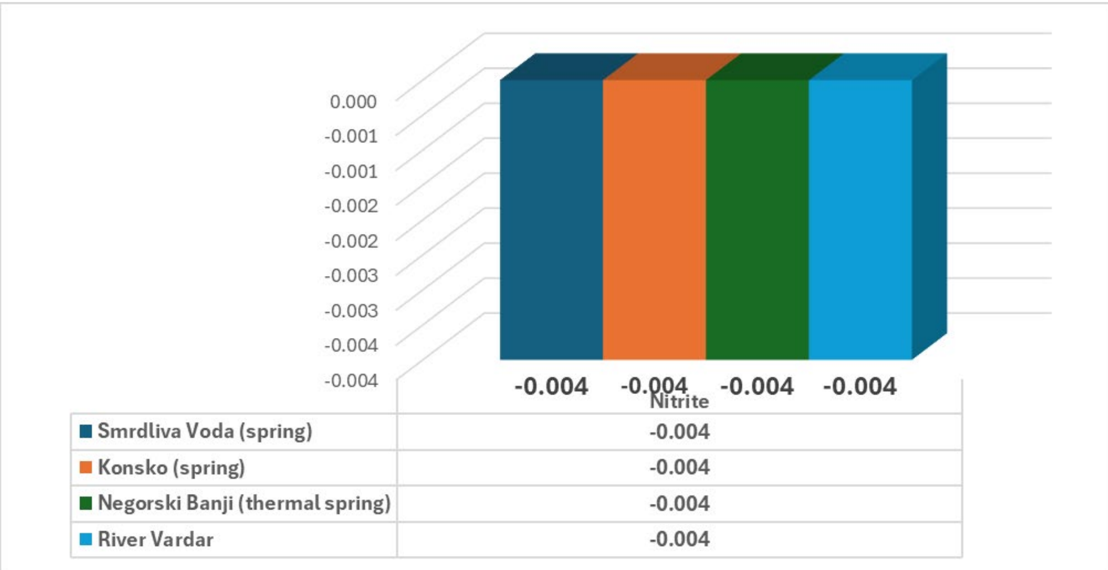

Figure 25. Comparison between the measuring points (springs and river) for nitrite presence

Figure 13 represents the comparison between all four measuring points by the measuring parameter potassium/calcium. According to the measured and represented results in Table 1, the potassium level in Smrdliva Voda, and Konsko as a mountain spring is near the average potassium level of 10 mg/L. However, in Negorski Banji as a thermal spring, the potassium concentration is greater since that water contains a larger amount of minerals. But still, the potassium level is not extremely high. The potassium level in the human body could be calculated according to the table presented in [19]. The potassium levels in the water are not high enough to cause worrisome effects.

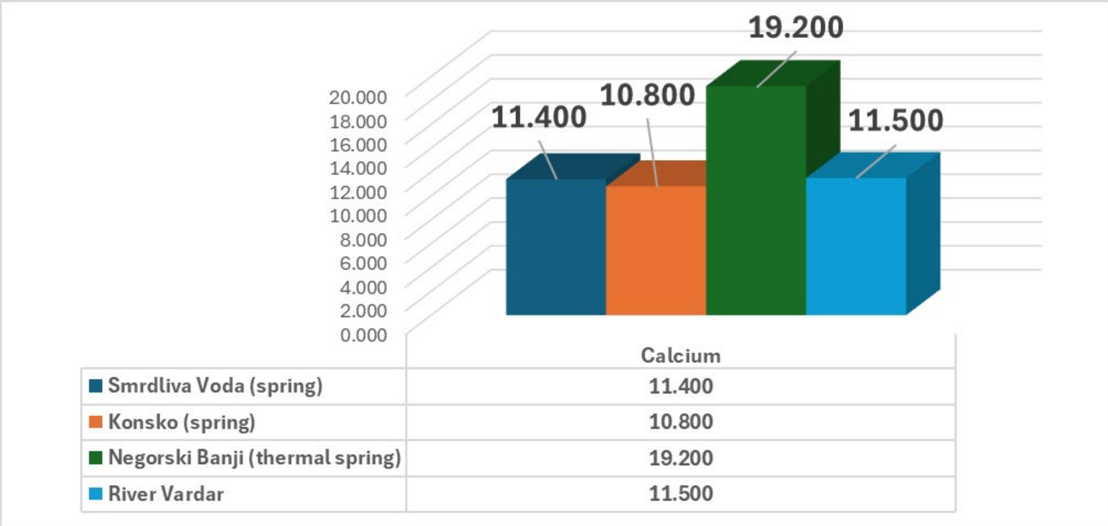

Figure 26. Comparison between the measuring points (springs and river) for potassium/calcium presence

Figure 14 represents the comparison between all four measuring points by the measuring parameter ammonium. According to the results, it is evident that Smrdliv Voda Spring, Konsko Spring, and Negorski Banji thermal spring are non-polluted water sources and that they are safe for drinking water. According to the WHO, the minimal level of pollution in drinking water is 0.25 mg/L, even Vardar River has a lower level of the minimum permitted level of pollution.

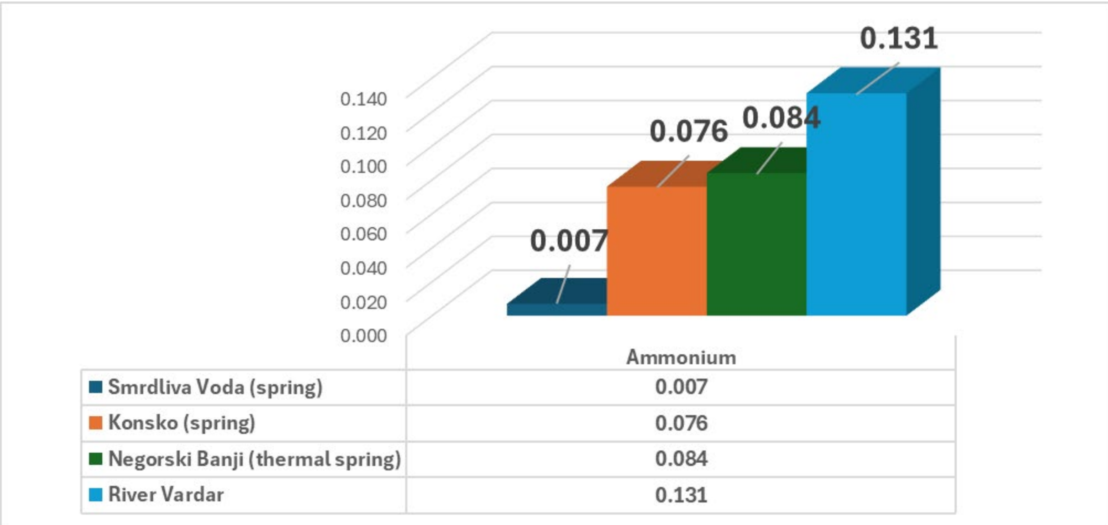

Figure 27. Comparison between the measuring points (springs and river) for ammonium presence

Figure 15 represents the comparison between all four measuring points by the measuring parameter phosphate.

The phosphate presence in the water does not harm human health but it stimulates plant growth. According to the measured results, the phosphate level in Negorski Banji thermal spring and in Smrdliva Voda spring, is the highest, meaning lush vegetation. That is proved when the situation on-site is checked.

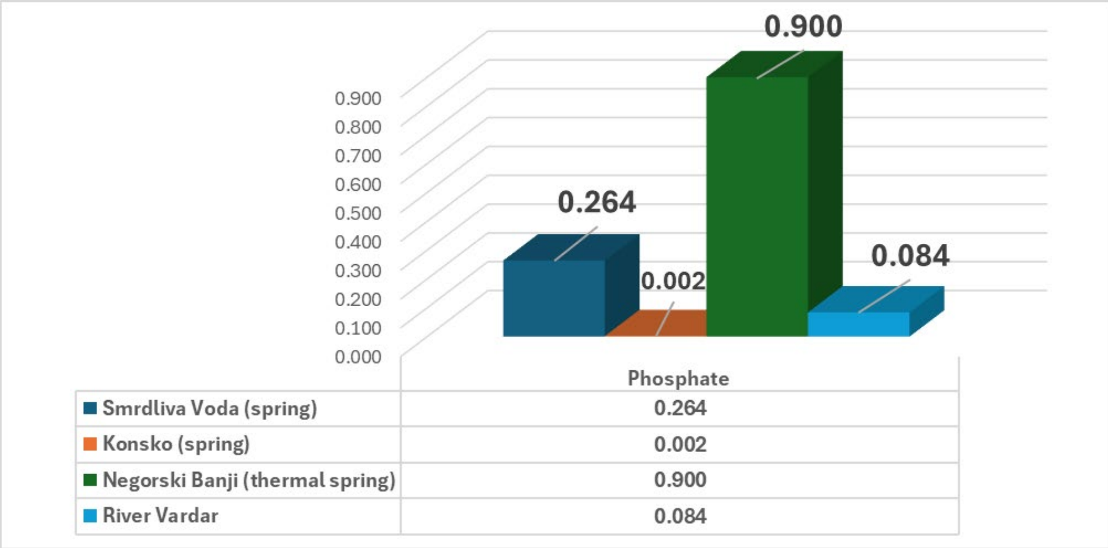

Figure 28. Comparison between the measuring points (springs and river) for phosphate presence

5. Conclusion

In this paper, water quality measurement with UV-VIS spectrophotometer HACH Lange DR 6000 and high-speed temperature thermostat HT 200 S is done. Measured parameters are chlorides, nitrates, nitrites, potassium, phosphates, and ammonium. During the sample-taking, measuring, and analyzing process, four measuring points were taken into consideration, Smrdliva Voda spring, Konsko spring, Negorski Banji thermal spring, and Vardar River. All the water points, except the Vardar River are considered as drinking water and people use them daily. According to the measured parameters, the results, and the analysis, the water from all four measuring points does not contain any waste discharges or agricultural runoff. According to the minimum and maximum values for each measured parameter separately announced by the WHO, neither of the parameters doesn't exceeds the proposed range.

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