Microbiological and Physicochemical Research of Thermal Spring and Mountain Spring Waters in the District of Sliven, Bulgaria

Nedyalka Valcheva¹, Ignat Ignatov²* and Georgi Dinkov³

¹Department of Biochemistry, Microbiology and Physics, Faculty of Agriculture, Trakia University, Stara Zagora 6000, Bulgaria.
²Scientific Research Center of Medical Biophysics, 32 Nikolai Kopernik St., 1111 Sofia, Bulgaria.
³Idealabs, LLC, 18th Street NW, #700, Washington 20036, USA.

Authors’ contributions

This work was carried out in collaboration among all authors. Author NV designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors II and GD managed the analyses of the study. Author II managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Defined are the physicochemical properties of four healing non-thermal and thermal spring waters in the area of Sliven District, Bulgaria. The spring waters from the given four water sources are characterized by microbiological indicators and the pathogenic micro-organisms in the samples from the springs water sources mentioned above are determined by the membrane method. It is shown that according to 18 controlled parameters included in the study, the non-thermal healing spring “Hadji Dimitar” in the area of “Hot water” in the town of Shivachevo with water temperature 22.5°C and the non-thermal spring “Gunchov spring” with water temperature 21.5°C correspond to all controlled parameters according to Ordinance NO 9/2001, Official State Gazette, issue 30 and decree NO 178/23.07.2004 about the quality of water, intended for drinking purposes. It is established that that thermal healing spring Sliven mineral baths with water temperature 48°C,
healing spring Banya village with water temperature 37°C meet the standard requirements. Non-thermal spring "Gunchov Spring", Silven district with water temperature 21.5°C does not meet the required microbiological parameters in regards to coli bacteria levels.

Keywords: Spring water; physicochemical properties; microbiological indicators.

1. INTRODUCTION

The causes for that lie in the combination between hydrological conditions of the continuing tectonic processes in the Earth’s crust [1,2]. By their nature the springs can be separated in cold, warm and hot springs. The first group includes the ones with temperature up to 37°C and this is cold mineral water. The second one ranges between 37°C and 60°C and this is warm mineral water. The third one with over 60°C and this is hot mineral water. The hottest mineral spring in Bulgaria is the one at Sapareva Banya with temperature of 101.4°C. The springing waters have different mineralogical characteristics. Their content is defined by the ones of the rocks, where the water has been flowing through, and the solubility of the minerals within them (Ignatov, Mosin, 2012). The research with hot mineral water from Rupite, Bulgaria with HCO₃⁻-1320-1488 Ca²⁺-29-36 mg/dm³ shows the possibility of origin of life in hot mineral water [1,2].

Several authors [3,4,5] The temperature of the water of the source is 76°C and in the lake is around 50°C and is depending with season. There are proofs for cyanobacteria in hot mineral water in Rupite [6]. This water contains the following ions and they are structured the first living organisms – stromatolites.

In Bulgaria, there are mineral and spring waters, which are not subjected to physicochemical and microbiological control by the Regional Health Inspectorate, yet they are the most widely used springs by the population as sources of drinking water. Similar springs are located in the territory of Haskovo District [7-9], Stara Zagora District [10,11], Varna District [12] and Burgas District [13,14].

For many of these sources physicochemical and microbiological studies have not been conducted, yet they are used for drinking and household needs [15].

Water is an environment for the development of microorganisms. Studies by many authors, including our research team, demonstrate that microorganisms with valuable properties (enzymes, antibiotics, thermophilic and acidophilic stains) are present in mineral and non-thermal spring waters.

This was proved by the results obtained from the experimental work carried out to determine the micro flora of medicinal and spring waters in Haskovo, Stara Zagora, Burgas [7-14] and Varna region [12].

There are different studies of physicochemical and microbiological properties of hot mineral waters [16-19] etc.

Isolated bacteria from the healing and spring regions have been identified by physiologico-biochemical and well as molecular genetic tests and the species include Bacillus subtilis, Bacillus cereus, Bacillus thuringiensis, Bacillus methylotrophicus, Aeromonas hydrophila.

The research of Bacillus subtilis in hot mineral water were performed from Asoodeh, Lagzian [19] and with one of the authors [2]. There was study for effects of Bacillus subtilis in heavy water with parameters for study in mineral water [21-23]. The study of Bacillus methylotrophicus was made in hot water from Tumbarski, et al. [24] and Yuan, et al. [25]. For the first time Aeromonas hydrophila was observed in hot mineral water from Italian team [26]. One of the authors Valcheva has performed the study with Bacillus cereus and Bacillus thuringiensis [15].

Strains with high proteolytic, lipolytic and amylolytic activity have been isolated and standardized for further scientific use [8-14].

Antimicrobial activity of the strains of Bacillus sp., was detected against the following saprophytic and pathogenic microorganisms: Penicillium sp., Fusarium moliniforme, Rhizopus sp., Aspergillus niger, Aspergillus oryzae, Aspergillus sawamori, Mucor sp. and Enterococcus faecalis, in the process of development and growth of the four Bacillus – Bacillus cereus, Bacillus thuringiensis, Bacillus subtilis, Bacillus methylotrophicus are the most active strains -
Pathogenic bacteria exhibit resistance and retain their vitality in the process of development and interaction between them and the strains of Bacillus sp. at temperature of 37°C.

A relatively low bactericidal effect was demonstrated against the (Gr+) bacterium Enterococcus faecalis. The isolated strains are likely to have a higher inhibitory ability against (Gr-) bacteria compared to (Gr+) bacteria.

The yeasts used in the genus Candida exhibit a simulating effect on the growth of Bacillus sp. – Bacillus methylotrophicus PY5 (Я1), and Bacillus cereus LH1 (P1). This indicates that synergism has occurred between these microorganisms.

The sources from Sliven district, Bulgaria for research are:

2. WATER SPRINGS FOR RESEARCH FROM SLIVEN DISTRICT, BULGARIA

2.1 Sliven Mineral Baths

The mineral water is hot (48°C), low-mineralized (1,986 g/dm³), hydrocarbonate - sulphate - sodium and calcium, slightly fluorine (4.2 mg fluorine per dm³). It contains 27 mg colloidal metasilicic acid per liter, neutral reaction (pH 6.8) due to its CO₂ content (287 mg / dm³). Water from this source is effective in the treatment of gastrointestinal diseases, liver and bile diseases, diseases of the musculoskeletal system, diseases of the peripheral nervous system, endocrine diseases, and skin diseases. It has a general anti-inflammatory effect on the body, improves blood circulation and influences on toxins.

2.2 Non-thermal Spring, Hadji Dimitar, “Hot Water Area”, Town of Shivachevo

The captive natural spring “Hadji Dimitar” is located north of the town of Shivachevo in the southern slopes of the Balkan Range at an altitude of 480 meters. Depending on the season, its flow rate ranges from 4.5 to 5.5 liters per second, with a temperature of 22-30°C. The total mineralization of a captive healing spring, Hadji Dimitar is 392 mg/dm³. The mineral water is characterized as hypothermal, low mineralized, hydrocarbonate - calcium - magnesium water. Tested levels of micro-components are within normal limits except for arsenic content. If used for drinking water, it is necessary to reduce arsenic within the normal range. The water from this source is suitable for the treatment of diseases of the musculoskeletal system, the peripheral nervous system, gastrointestinal diseases, bile-liver diseases and nephro-urological.

2.3 Thermal Healing Spring Banya Village

The village of Banya, with its thermal mineral springs (37°C), combined with the beautiful nature and modern infrastructure, and provides the perfect conditions for complete recovery! It is suitable for the treatment of the following types of diseases – allergies, arthritis, lung disease, back pains, depression, and diabetes.

The established Health Recovery Center combines the most effective recovery package - healthy food, healing gymnastics, many group walks in the unique surroundings, food exclusively of plant origin (vegan), relaxing massages, water treatments with mineral water, with herbs or different salts, compresses and heat-pads, different saunas, inhalations, exercises, juice therapy and herbal teas as needed.

2.4 Mountain Spring “Gunchov Spring”, Karandila Locality, Sliven District

The spring is located among the most densely forested areas along the Ravna River. The whole area is overgrown with dense beech forest, which is where centuries-old trees can be found here. The spring is located in the Blue Stones Park above Sliven.

3. MATERIALS AND METHODS

This study used the water samples from the following springs in the district of Sliven. There are “Sliven Mineral Baths”, “Hadji Dimitar”, “Banya”, “Gunchov spring”.

A comparative physicochemical analysis of mineral spring waters at the territory of Sliven District was performed using the main indicators (color according to Rublyovska Scale, smell at 20°C, turbidity, pH, oxidisability, chlorides, nitrates, nitrites, ammonium ions, general hardness, sulphates, calcium, magnesium,
phosphates, manganese, iron, fluorides, electrical conductivity).

3.1 Nutrient Media

Nutrient agar (MPA) with contents (in %) – meat water, peptone – 1%, agar – agar – 2%.

Endo’s Medium (for defining of Escherichia coli and coliform bacteria) with contents (g/dm³) – peptone – 5,0; triptone – 5,0; lactose – 10,0; Na₂SO₃ – 1,4; K₂HPO₄ – 3,0; fuchsine – 0,14; agar – agar – 12,0 pH 7,5 – 7,7.

Nutrient gelatin (MPD) (for defining of Pseudomonas aeruginosa) with contents (in%) – Peptic digest of animal tissue; 25% gelatin ;рН = 7, 0 – 7, 2.

Medium for defining of enterococci (esculin – bile agar).

Medium for defining of sulphite reducing bacteria (Iron Sulfite Modified Agar).

Wilson-Bleer medium (for defining of sulphite reducing spore anaerobes (Clostridium perfringens) with contents (g/dm³) – 3%.

3.2 Methods for Analysis

3.2.1 Methods for physicochemical analysis

1. Method for determination of color according to Rublyovska Scale – method by Bulgarian State Standard (BDS) 8451: 1977;
2. Method for determination of smell at 20°C — method BDS 8451: 1977 technical device – glass mercury thermometer, conditions No 21;
3. Method for determination of turbidity - EN ISO 7027, technical device turbidimeter type TURB 355 IR ID No 200807088;
4. Method for determination of pH – BDS 3424: 1981, technical device pH meter type UB10 ID No UB10128148;
5. Method for determination of oxidisability – BDS 3413: 1981;
6. Method for determination of chlorides – BDS 3414: 1980;
7. Method for determination of nitrates – Validated Laboratory Method (VLM) – NO₃ – No 2, technical device photometer "NOVA 60 A" ID No 08450505;
8. Method for determination of nitrites – VLM NO₂ – No 3, technical device photometer "NOVA 60 A" ID No 08450505;
9. Method for determination of ammonium ions – VLM – NO₄ – No 1, technical device photometer "NOVA 60 A" ID No 08450505;
10. Method for determination of general hardness – BDS ISO 6058;
11. Method for determination of sulphates – VLM - SO₄ – No 4, technical device photometer "NOVA 60 A" ID No 08450505;
12. Method for determination of calcium – BDS ISO 6058;
13. Method for determination of magnesium – BDS 7211: 1982;
14. Method for determination of phosphates – VLM - P0₄ – No 5, technical device photometer "NOVA 60 A" ID No 08450505;
15. Method for determination of manganese – VLM – Mn – No 7, technical device photometer "NOVA 60 A" ID No 08450505;
16. Method for determination of iron – VLM – Fe – No 6, technical device photometer "NOVA 60 A" ID No 08450505;
17. Method for determination of fluorides – VLM – F – No 8, technical device photometer "NOVA 60 A" ID No 08450505;
18. Method for determination of electrical conductivity – BDS EN 27888, technical device – conductivity meter inoLabcond 720 ID No 11081137.

3.2.2 Methods for determination of microbiological indicators

1. Methods for evaluation of microbiological indicators according to Ordinance No 9 / 2001, Official State Gazette, issue 30 and decree No 178 / 23.07.2004 about the quality of water, intended for drinking purposes.
2. Method for determination of Escherichia coli and coliform bacteria – BDS EN ISO 9308 – 1: 2004;
3. Method for determination of enterococci – BDS EN ISO 7899 – 2;
4. Method for determination of sulphite reducing spore anaerobes – BDS EN 26461 – 2: 2004;
5. Method for determination of total number of aerobic and facultative anaerobic bacteria – BDS EN ISO 6222:2002;
6. Method for determination of Pseudomonas aeruginosa – BDS EN ISO 16266: 2008.
7. Determination of coli – titer by fermentation method – Ginchev’s method (Bulgarian standard);
8. Determination of coli – bacteria over Endo’s medium – membrane method.

Determination of sulphite reducing anaerobic bacteria (Clostridium perfringens) – membrane method.

4. RESULTS AND DISCUSSION

The results from the tests of physicochemical research with are given in Table 1.

Also, the microbiological indicators for the same spring waters were determined by the membrane method. The experimental studies from the determination of total number of mesophilic aerobic and facultative anaerobic bacteria are shown in Table 2.

According to the standard requirements from the examined water samples from the four springs, the water is clean.

The presence of coli forms and Escherichia coli is determined by the membrane method and according to Ginchev’s method (Bulgarian standard). The experimental results (Tables 3 and 4) reveal “Sliven mineral baths”, “Hadji Dimitar” and “Banya”, are in compliance with the requirements for presence of coli bacteria. Non-Thermal healing spring “Gunchov spring” does not comply with the requirements for presence of coli form bacteria and enterococci.

The present results for those springs are also confirmed by the analyses via the membrane method (Table 4). All the remaining indicators are determined by the membrane method.

Table 1. Comparison of the examined spring waters in Sliven District by physicochemical properties

| Controlled parameter | Measuring unit | Maximum limit value | Result sliven mineral baths | Result Hadji Dimitar Shivachevo | Result village of Banya | Result Gunchov spring |
|----------------------|----------------|---------------------|-----------------------------|---------------------------------|------------------------|------------------------|
| Color Rublyovska Scale Chromaticity Values | Acceptable | Acceptable | Acceptable to Acceptable | Acceptable to Acceptable | Acceptable to Acceptable | Acceptable to Acceptable |
| Smell at 20°C Rating | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable |
| Turbidity NTU pH values | ≥ 6,5 и ≤ 9,5 | 6.91 | 7.49 | 7.90 | 7.19 |
| Oxidisability mgO₂/dm³ | ≤5.0 | 1.6 | 1.12 | 1.6 | 1.12 |
| General hardness mgekv/ dm³ | ≤12 | 8.55 | 5.2 | 8.55 | 5.32 |
| Chlorides mg/ dm³ | ≤250 | 60.28 | 3.55 | 45.7 | 2.66 |
| Nitrates mg/ dm³ | ≤50 | <5.0 | <1.0 | <0.007 | 0.006 |
| Nitrates mg/ dm³ | ≤0.50 | <0.05 | <0.05 | <0.05 | 0.07 |
| Ammonium ions mg/ dm³ | ≤0.50 | <0.05 | <0.05 | <0.05 | 0.093 |
| Sulphates mg/ dm³ | ≤250 | 475.28 | 16.95 | 165 | 84 |
| Calcium mg/ dm³ | ≤150 | 98.2 | 50.1 | 110 | 88 |
| Magnesium mg/ dm³ | ≤80 | 30.4 | 24.32 | 37.21 | 61 |
| Phosphates mg/ dm³ | ≤0.5 | 0.006 | <0.02 | <0.006 | <0.03 |
| Manganese mg/ dm³ | ≤50 | 0.08 | <0.02 | 15 | 2 |
| Iron µg/ dm³ | ≤200 | 0.41 | 0.02 | 0.0037 |
| Fluorides mg/ dm³ | ≤1,5 | 7.73 | 0.4 | 1.48 | 0.01 |
| Electrical conductivity µS/ dm3 | ≤2000 | 21.1 | 422 | 450 | 701 |

Norm: The indicator with red color is not in norm. The result is 475.28 and the norm for Sulphates is ≤250 mg/ dm³

Table 2. Determination of total number of mesophilic aerobic and facultative anaerobic bacteria

| Examined water source | Indicator, cfu/cm³ |
|-----------------------|--------------------|
| 1. Thermal healing spring Sliven Mineral baths with water temperature of 48°C | 7 ± 1 |
| 2. Non-thermal healing spring “Hadji Dimitar” locality “Hot water” town Shivachevo with water temperature 22.5°C | 6 ± 1 |
| 3. Healing spring Banya village with water temperature 37°C | 5 ± 1 |
| 4. Non-thermal “Gunchov Spring”; Karandila locality with water temperature 21.5°C | 80 - 90 |
Table 3. Coli – titre of thermal healing spring waters in Sliven District

| Name of water source                                      | Coli-titre | Culture volumes 50 cm³ | Culture volumes 10 cm³ | Culture volumes 10 cm³ | Culture volumes 10 cm³ | Culture volumes 10 cm³ |
|-----------------------------------------------------------|------------|-------------------------|------------------------|------------------------|------------------------|------------------------|
| 1. Thermal healing spring Sliven Mineral baths with water temperature of 48°C | > 100      | –                       | –                      | –                      | –                      | –                      |
| 2. Non-thermal healing spring "Hadji Dimitar" with water temperature 22.5°C | > 100      | –                       | –                      | –                      | –                      | –                      |
| 3. Thermal healing spring Banya village with water temperature 37°C | > 100      | –                       | –                      | –                      | –                      | –                      |
| 4. Non-thermal "Gunchov Spring", Karandila locality with water temperature 21.5°C | 80         | +                       | +                      | Acid                   | Acid                   | Acid and gas           |

Table 4. Microbiological indicators of spring waters in Sliven District

| Indicators                                                                 | Norm       | Measuring unit | Thermal healing spring sliven mineral baths with water temperature of 48°C | Thermal healing spring "Hadji Dimitar" locality "Hot water" town Shivachevo with water temperature 22.5°C | Thermal healing spring Banya village with water temperature 37°C | Non-thermal "Gunchov Spring", Karandila locality with water temperature 21.5°C |
|---------------------------------------------------------------------------|------------|----------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Coliforms                                                                 | 0/100      | cfu/cm³        | 0/100                                                                        | 0/100                                                                                                                                          | 0/100                                                              | 0/100                                                                            |
| Escherichia coli                                                           | 0/100      | cfu/cm³        | 0/100                                                                        | 0/100                                                                                                                                          | 0/100                                                              | 0/100                                                                            |
| Enterococci                                                               | 0/100      | cfu/cm³        | 0/100                                                                        | 0/100                                                                                                                                          | 0/100                                                              | 0/100                                                                            |
| Sulphite reducing anaerobic bacteria (Clostridium perfringens)            | 0/100      | cfu/cm³        | 0/100                                                                        | 0/100                                                                                                                                          | 0/100                                                              | 0/100                                                                            |
| Pseudomonas aeruginosa                                                    | 0/250      | cfu/cm³        | 0/250                                                                        | 0/250                                                                                                                                          | 0/250                                                              | 0/250                                                                            |

The result with red color is not in norm
5. CONCLUSION

Based on the conducted physicochemical and microbiological evaluations it is established that from the four examined springs at the territory of Sliven district, Bulgaria thermal healing mineral spring "Banya" and non - thermal healing spring "Hadji Dimitar" locality "Hot water" town Shivachevo source correspond to all controlled parameters according to Ordinance No 9/2001, Official State Gazette, issue 30 and decree № 178/23.07.2004 about the quality of water, intended for drinking purposes.

With regards to physicochemical parameters of "Gunchov spring" from controlled parameters according to Ordinance No 9/2001, Official State Gazette, issue 30, and decree № 178/23.07.2004 about the quality of water is in compliance with the with the requirements for drinking water.

With regards to microbiological parameters thermal healing water "Sliven Mineral baths" source is in compliance with the requirements for drinking water.

STANDARDS

1. Ordinance No 9 / 2001, Official State Gazette, issue 30.
2. Decree No 178 / 23.07.2004 about the quality of water, intended for drinking purposes.
3. BDS 8451: 1977 – defining of color according to Rublyovska Scale, determination of smell at 20°C.
4. EN ISO 7027 – determination of turbidity.
5. BDS 3424: 1981 – determination of pH.
6. BDS 3413: 1981 – determination of oxidisability.
7. BDS 3414: 1980 – determination of chlorides.
8. BDS ISO 6058 – determination of calcium, determination of general hardness.
9. BDS EN 27888 – determination of electrical conductivity.
10. VLM – NH₄ – No 1 – determination of ammonium ions.
11. VLM – NO₃ – No 2 – determination of nitrates.
12. VLM – NO₂ – No 3 – determination of nitrites.
13. VLM – SO₄ – No 4 – determination of sulphates.
14. VLM – PO₄ – No 5 – determination of phosphates.
15. VLM – Fe – No 6 – determination of iron.
16. VLM – Mn – No 7 – determination of manganese.
17. BDS 7211: 1982 – determination of magnesium.
18. BDS EN ISO 7899 – 2 – determination of nitrates.
19. BDS EN ISO 9308 – 1: 2004 – determination of Escherichia coli and coliform bacteria.
20. BDS EN ISO 26461 – 2: 2004 – determination of sulphite reducing anaerobic bacteria (Clostridium perfringens).
21. BDS EN ISO 16266 – determination of Pseudomonas aeruginosa.
22. BDS EN ISO 7899 – 2 – determination of enterococci.
23. BDS EN ISO 6222: 2002 – determination of total number of aerobic and facultative anaerobic bacteria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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