

Date: 13th September-2026

CHARACTERIZATION OF BALNEOLOGICAL MINERAL WATERS (SPRINGS) AND EXPERIENCES IN THEIR STUDY

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Abstract. The article examines the formation, physicochemical composition, therapeutic properties, and classification characteristics of balneological mineral waters (springs). The significance of biologically active components, temperature, pH, and ionic-salt composition in determining the therapeutic properties of mineral waters is analyzed. The stages of development in the study of mineral springs, from ancient times to the present day, are also considered. Particular attention is given to the importance of hydrogeological, hydrochemical, and cartographic approaches in the investigation and assessment of mineral water resources.

Keywords: mineral springs, hydrogeological characteristics, physicochemical composition, therapeutic properties, degree of mineralization, biologically active components, hydrochemical studies, mineral water classification, cartographic studies.

Balneological mineral waters are considered one of the important natural resources used for restoring human health, treating diseases, and preventing various disorders. As a distinct type of groundwater, mineral waters are characterized by the presence of various biologically active components, ions, gases, mineral salts, temperature, and pH. Their therapeutic properties are primarily determined by their chemical composition, degree of mineralization, and physical characteristics.

Mineral springs are an important component of the natural geographical environment, and their formation and emergence at the Earth's surface are closely associated with geological, hydrogeological, and geomorphological conditions. From this perspective, the study of mineral waters makes it possible not only to determine their therapeutic properties but also to identify their spatial distribution patterns, genesis, and potential as natural resources.

The history of using mineral waters for therapeutic purposes dates back to ancient times. While treatment facilities were established around mineral springs in Ancient Greece and Rome, the scientific development of knowledge about mineral and thermal waters in Central Asia was significantly influenced by the scientific heritage of Abu Ali ibn Sina and Abu Rayhan al-Biruni.

During the seventeenth to twentieth centuries, hydrogeological and hydrochemical investigations, laboratory analyses, classification methods, and cartographic approaches became increasingly developed in the study of mineral waters. As a result, scientific classification systems were developed based on the ionic and salt composition, gases, and biologically active components of mineral waters, while specialized maps were created to represent their spatial distribution.



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Therefore, the comprehensive study of the natural characteristics of balneological mineral waters (springs), assessment of their physicochemical composition and therapeutic significance, and improvement of research methodologies remain important scientific and practical objectives. Such studies are particularly relevant for the rational use, conservation, and sustainable management of balneological water resources.

INTRODUCTION

The term “balneology” is of Latin origin and is associated with the concepts of “taking a bath” or “bathing.” More specifically, it refers to the therapeutic use of warm baths with natural mineral and thermal waters that differ in temperature, chemical composition, or viscosity, including both pure liquid waters and therapeutic muds. The concept is directly related to the term “resort,” which refers to places where bathing and therapeutic treatment are provided¹.

Groundwater can be classified into three main categories: fresh water used for domestic and drinking water supply; mineral waters possessing therapeutic properties; and industrial waters used for the extraction of valuable components such as Na, Cl, I, Br, and other useful substances².

According to A.M. Ovchinnikov, medicinal mineral waters are defined as natural waters that exert a therapeutic effect on the human body due to an increased concentration of biologically active components, their ionic or gaseous composition, and the overall ionic-salt composition of the water. In other words, mineral waters are natural waters possessing therapeutic properties [1].

Depending on the concentration of the main biologically active components present in mineral waters (CO₂, H₂S + HS⁻, As, Fe, Br, I, B, H₂SiO₃, Rn, and organic substances), they are classified into the following types: carbonated, hydrogen sulfide, iron-rich, bromide, iodide, boron-rich, arsenic, siliceous, radon, and organic mineral waters, respectively (Table 1). The therapeutic properties of mineral waters are also determined by their temperature and the pH of the aqueous medium [2].

Table 1

Classification of mineral waters by biologically active components

(B.C.Назаренко, O.B.Назаренко, B.B.Назаренко,)

№	Type of Mineral Water	Main Component	Formula	Factor Determining Therapeutic Properties
1.	Carbonated	Carbon dioxide	CO ₂	Gas composition
2.	Hydrogen sulfide	Hydrogen sulfide	H ₂ S, HS ⁻	Sulfur-containing compounds
3.	Iron-rich	Iron	Fe	Iron ions
4.	Bromide	Bromine	Br ⁻	Bromide ions
5.	Iodide	Iodine	I ⁻	Iodide ions

¹ K.Popovski, S.P.Vasilevska – BALNEOLOGY (илмий кўлланма/скрипта кўринишидаги материал)
<https://geocom.geonardo.com/assets/elearning/4.1.BALNEOLOGY.pdf>

² Минькевич И.И., Нуриев И.С., Шестов И.Н. Минеральные воды: учебное пособие. — Казань: Казанский университет, 2012. — 127 с.



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6.	Boron-rich	Boron	B	Boron compounds
7.	Arsenic	Arsenic	As	Arsenic compounds
8.	Siliceous	Silicic acid	H ₂ SiO ₃	Silicon compounds
9.	Radon	Radon	Rn	Radioactivity
10.	Organic	Organic substances	—	Organic components

The presence of iodine, bromine, lithium, barium, iron, and other chemical elements, as well as gases such as carbon dioxide, radon, and sulfur-containing gases, contributes to the therapeutic properties of mineral waters.

Sulfate-hydrocarbonate Narzan waters are found in Kislovodsk, while carbonated mineral waters occur in Zheleznovodsk, Pyatigorsk, and Essentuki. Sulfur-rich mineral waters are present in Chimgan and Uchqizil (Uzbekistan), Obishifo (Tajikistan), and Matsesta (Georgia). Nitrogen-rich mineral waters are found in Qiziltepa (Uzbekistan) and Issyk-Ata (Kazakhstan), whereas radioactive mineral waters occur in Khoja-Obigarm (Tajikistan) and Jeti-Oguz (Kazakhstan). Numerous other regions are also known for their mineral water springs.

The use of mineral waters as balneological resources dates back to the 5th century BCE and represents an integral part of the historical development of spa and resort medicine [3].

The use of water has been of great importance to human life throughout history. In some religious traditions, water has also been used for purification and therapeutic purposes.

The Babylonians regarded physicians as specialists in water-based treatments, as they used hot and cold compresses and incorporated bathing in mineral waters into therapeutic practices [4].

Baths played an important role in Ancient Greek civilization. Initially, people used individual baths; however, they later shifted to communal bathing facilities, as bathing was regarded as a therapeutic practice for the treatment of diseases. From this period onward, the use of mineral waters for therapeutic purposes began to develop [5].

Гиппократ (мил. авв.460–370) тўрта муҳим элементни (сув, ҳаво, олов ва ер) соғлиқ ёки касаллик ҳолатини белгилайдиган омил сифатида белгилаб берди [6].

Asclepiades, who lived in the 2nd century BCE (approximately 124–40 BCE), widely employed hydrotherapy as an effective method for treating various diseases. He did not limit water therapy to external treatments but also recommended the internal consumption of mineral and natural waters as a therapeutic and preventive measure aimed at both treating diseases and preventing their occurrence [7].

Galen (131–201 CE) advocated the use of water, particularly cold water, in the treatment of various diseases. This concept was subsequently adopted and practiced for nearly two millennia. Through the influence of the Roman Empire, water and bathing became an important part of European civilization [8].

In Ancient Greece, most of the mineral springs that were discovered were sulfur-rich waters. Later, the Greeks' knowledge of the therapeutic properties of mineral waters



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was adopted by the Romans. According to Roman beliefs, all mineral waters were of divine origin. Some cities in the province located near Mount Vesuvius, which was particularly rich in thermal springs, became among the most renowned balneological centers during the period between antiquity and the modern era.

During the Middle Ages, knowledge of mineral and thermal waters in Central Asia became increasingly developed from a scientific perspective. In this regard, the scientific heritage of the great scholars of the region played a particularly important role.

The contribution of Abu Ali ibn Sina (980–1037) is of particular significance. In his renowned work *Al-Qanun fi al-Tibb* (The Canon of Medicine), he presented scientifically grounded information on the physicochemical properties of natural mineral waters, including their temperature, taste, composition, and physiological effects on the human body. Ibn Sina classified mineral waters according to their principal constituents into sulfurous, saline, iron-rich, and other types, and described their importance in the treatment and prevention of various diseases. These views played an important role in the formation of the scientific principles of balneotherapy.

Abu Rayhon al-Beruniy (973–1048) explained the formation, movement, and emergence of groundwater at the Earth's surface on the basis of scientific concepts that were advanced for medieval science. In his works, he emphasized that groundwater movement was associated with the geographical location of recharge areas. He analyzed the formation of springs, the upward movement of groundwater toward the Earth's surface, and patterns of their spatial distribution, and attempted to scientifically substantiate the formation of their chemical composition through prolonged interaction between groundwater and geological rocks³.

In subsequent periods, the development of research on mineral waters was particularly evident in European countries. In particular, sodium-chloride mineral waters in Europe had been known since the Middle Ages, with the earliest records dating back to the thirteenth and fourteenth centuries [17].

Interest in mineral waters was revived particularly during the period of the Crusades (1096–1270) and the Hundred Years' War between France and England (1337–1453). Hospitals were subsequently established near mineral springs. The first publications describing the therapeutic properties of French mineral springs appeared during the fifteenth and sixteenth centuries.

In Italy, the history of the use of mineral waters dates back several thousand years. The mineral waters of Abano Terme have been known since the establishment of the settlement of Aponium in ancient Rome. The development of this therapeutic center began in the thirteenth century. Today, it is considered one of the largest mud-therapy spa resorts in Europe [18].

In the sixteenth century, the first studies aimed at providing a scientific basis for the therapeutic use of mineral waters began at the famous Karlovy Vary spa resort in the Czech lands. This process is closely associated with the scholar W. Payer (1480–1537). In

³ Sobirjonov M.M. BALNEOLOGICAL RESOURCES AND ISSUES OF THEIR USE. INTERNATIONAL SCIENTIFIC JOURNAL: LEARNING AND TEACHING, (2026) 3(1), 44–69. <https://zenodo.org/records/18314501>

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1522, he published one of the earliest works providing a scientific description of the therapeutic properties of the mineral springs of Karlovy Vary. In subsequent centuries, clinical observations and scientific investigations led to the widespread introduction of drinking mineral water cures alongside external balneotherapy. This contributed significantly to the development of Karlovy Vary as one of the most prominent balneological centers in Europe [10].

In the sixteenth century, many prominent Italian physicians began to focus their attention on balneotherapy. However, rather than using water only in specific therapeutic circumstances, these physicians advocated its regular and systematic use for treatment [11].

From the seventeenth century onward, balneology and spa medicine began to develop rapidly in Europe. During this period, the therapeutic properties of mineral waters were increasingly investigated from a scientific perspective, and spa towns began to emerge around natural therapeutic springs. Although the mineral springs of Lucca and Montecatini Terme in Italy had been known since the Middle Ages, from the seventeenth century onward they began to be used systematically for therapeutic purposes⁴.

In France, during the seventeenth century, the mineral water resorts of Vichy and Bourbon-Lancy began to receive state support. These resorts were recommended by physicians of the royal court, who regarded their mineral waters as effective in the treatment of rheumatic, dermatological, gastrointestinal, and joint diseases. Subsequently, Vichy became one of the most renowned balneological centers in Europe and gained considerable international recognition during the nineteenth century⁵.

One of the oldest balneological centers in Hungary is the Borsec mineral spring resort, whose official development dates back to the early eighteenth century. During this period, the use of mineral springs became increasingly organized, and the first elements of spa infrastructure were established. In 1770, water from the Borsec mineral springs was bottled and exported to Vienna and Budapest for commercial sale [12].

During the seventeenth and eighteenth centuries, the German physician, chemist, and naturalist Friedrich Hoffmann (1660–1742) was one of the earliest scientists to investigate the chemical composition of mineral waters on a scientific basis. He analyzed mineral waters under laboratory conditions and identified the presence of free carbon dioxide (carbonic acid), sodium chloride (common salt), magnesium sulfate, calcium compounds, and other mineral salts. Hoffmann scientifically substantiated the relationship between the therapeutic effects of mineral waters and their chemical composition and degree of mineralization [13].

By the end of the eighteenth century, the scientific study and systematic classification of mineral waters in France had entered a new stage of development. This process was associated with the publication in 1785 of a work prepared by the French physician Joseph Carrère (1740–1802). In this fundamental work, the existing scientific literature on the mineral water springs known in France was compiled and systematized,

⁴ UNESCO World Heritage Centre. The Great Spa Towns of Europe, 2021.

⁵ Medical History, Supplement №.(10) 1990. 23-47.

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including information on the geographical location of mineral springs, their physical properties, the temperature of thermal waters, and their chemical composition. Carrère's catalogue is recognized as one of the most important bibliographic and scientific sources in the field of balneology at the end of the eighteenth century.

In 1822, the Swedish chemist J. J. Berzelius conducted detailed chemical analyses of the mineral springs in Karlovy Vary and contributed to the development of scientific methods for determining the composition of mineral waters [14].

During the 1960s and 1970s, maps of mineral and thermal waters at scales ranging from 1:500,000 to 1:2,000,000 were published in a number of Western European countries, including Hungary in 1961, Czechoslovakia in 1963, Austria in 1966, Portugal in 1970, France in 1973, Romania in 1974, Serbia in 1976, and other countries.

In 1975, the German hydrogeologist and balneological scientist Walter Carlé published the fundamental monograph entitled *Mineral and Thermal Waters of Central Europe: Geology, Chemistry and Genesis*. This work is regarded as one of the most comprehensive scientific studies of the mineral and thermal waters of Central Europe. A distinctive feature of the monograph is that it synthesizes the results of 1,402 chemical analyses of 702 mineral and thermal water sources and includes 15 thematic maps illustrating their spatial distribution and hydrogeological characteristics [15].

In the eighteenth century, the systematic study and scientific investigation of mineral waters expanded to Russia. Peter the Great is regarded as one of the pioneers of the scientific development of the therapeutic use of mineral waters in Russia. The Russian Academy of Sciences, established under the initiative of Peter the Great, played an important role in promoting research on mineral waters. The Academy organized scientific expeditions to various regions of the country to investigate mineral springs and their therapeutic properties. During this period, the first spa resorts based on iron-rich mineral waters were established in Karelia and Lipetsk [1].

V. Severgin (1765–1826), during his expeditions in the late eighteenth century, described the mineral springs and lakes of Russia, carried out their classification, and developed a program for subsequent scientific investigations.

P. Savenko (1828), F. Conradi (1831), and N. Drozdov (1839) described mineral springs that had been known since the sixteenth to eighteenth centuries, as well as a number of newly identified mineral water sources. They conducted investigations of the Mashuksky, Buguntinsky, Zheleznovodsky, Kislovodsky, and Berezovsky springs.

In 1853, N. Drozdov described the chemical composition of sulfurous waters (Pyatigorsk), hydroxide-containing waters (Essentuki), iron-rich waters (Zheleznovodsk), carbonated Narzan waters (Kislovodsk), and bitter-saline waters (Lisogorsk Station)⁶.

In 1855, a fundamental two-volume work was published by the Russian physician and balneologist K. Ivanovich (1794–1874). The work systematically presented scientific information on mineral water sources, therapeutic mud deposits, and spa resorts located within the Russian Empire. It provided detailed descriptions of their geographical

⁶ В.С.Назаренко, О.В.Назаренко, В.В.Назаренко - "Минеральные лечебные воды и грязи". Ростов-на-Дону "ЦБВР" 2008.

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distribution, hydrogeological characteristics, the physicochemical composition of mineral waters, medical indications, and methods of therapeutic use.

In 1863, S. Smirnov (1819–1911) established the first scientific balneological society in Pyatigorsk. The society published scientific articles and fundamental works that contributed to the development of the theoretical foundations of balneology.

At the end of the nineteenth and the beginning of the twentieth centuries, the mineral waters of the Baikal region were investigated by V. A. Obruchev, A. Gerasimov, and A. Gedroits. The first scientific article devoted to the mineral springs of the Baikal region was published by I. Bagashev in 1905.

The first classification of mineral waters based on their ionic composition was published by V. Sadikov in 1916. He proposed dividing all mineral waters into 49 groups according to the content of specific major ions and additionally distinguishing the waters according to their predominant ionic composition [16].

Between 1917 and 1920, A. Gerasimov, A. Ogilvie, and A. Stopnevich continued research on therapeutic mineral waters. They provided detailed descriptions based on the results of chemical analyses of mineral water sources in the North Caucasus, including Semigorsky, Zaporozhsk, Zheleznovodsk, Kumagorsk, Zhyly-Su, Sernovodsk, Goryachevodsk, Psekupsk (Goryachy Klyuch), Matsestinsky, Pyatigorsk, Essentuki, and Kislovodsk.

In 1923, M. Zemskov and P. Nevlin described the mineral water sources of the Caucasian Black Sea coast and assessed the prospects for their use for balneological purposes.

During the 1930s and 1940s, detailed hydrogeological studies in the North Caucasus and Transcaucasia were conducted by A. Gerasimov, A. Ovchinnikov, A. Ogilvie, Ya. Langwagen, N. Slavyanov, V. Rengarten, K. Pfaffengolts, E. Karstens, I. Volodkevich, and A. Demekhin. During this period, the theory of the genesis of carbonated mineral waters was further developed and refined. These studies provided an important scientific basis for subsequent investigations of mineral waters in the region [16].

In 1946, the first Map of Mineral Waters of the USSR at a scale of 1:10,000,000 was published under the editorship of A. Zens-Litovsky and N. Tolstikhin.

In 1964, a classification of groundwater developed by V. Ivanov and G. Nevrayev was published. This classification became widely used for the characterization and classification of mineral waters.

In 1969, the Map of Therapeutic Mineral Waters of the USSR, the Catalogue of Mineral Waters of the USSR, and an appendix to the Map of Mineral Waters of the USSR were published. These three publications constituted an integrated scientific system and provided a comprehensive characterization of groundwater mineral waters [16].

In 1977, the book Mineral Waters by E. Posokhova and N. Tolstikhin was of considerable scientific importance and served as a principal textbook on mineral waters for many years.

In 1995, G. Kulikov, A. Zhevlakov, and S. Bondarenko published the reference book Therapeutic Mineral Waters of the USSR.



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The balneological mineral waters studied above are still used for therapeutic purposes in sanatoriums and recreational facilities in various regions of the world. They are employed in a range of health-oriented treatments, including balneotherapy (therapeutic bathing) and drinking therapy (internal use of mineral water), aimed at improving and maintaining human health (Table 2).

Table 2

Countries with extensive use of balneological mineral waters (springs)

№	Country	Famous Mineral Water Resorts	Mineral Water Composition	Therapeutic Applications
1.	Germany	Baden-Baden, Wiesbaden, Bad Kissingen	Sulfate, bicarbonate, thermal	Joint disorders, digestive system, nervous system
2.	France	Vichy, Évian-les-Bains, Contrexéville	Calcium-magnesium bicarbonate	Gastrointestinal system, kidney disorders
3.	Italy	Salsomaggiore Terme, Fiuggi, Bagno Vignoni	Iodine-rich, sodium-rich, hydrogen sulfide	Skin conditions, endocrine system
4.	Czech Republic	Karlovy Vary, Mariánské Lázně, Františkovy Lázně	Sodium bicarbonate-sulfate	Hepatobiliary system, diabetes, kidney disorders
5.	Russia	Kislovodsk, Pyatigorsk, Essentuki, Zheleznovodsk	Sulfate, sodium bicarbonate	Cardiology, gastrointestinal system, nervous system
6.	Hungary	Budapest (Gellért, Széchenyi), Hévíz	Radon, thermal, sulfate	Rheumatology, orthopedics, dermatology
7.	Japan	Beppu, Hakone, Kusatsu	Hydrogen sulfide, iron-rich, carbonated	Arthritis, nervous system, skin diseases
8.	Spain	Caldes de Malavella, Archena, Mondariz	Calcium-magnesium sulfate	Stress relief, dermatological treatment, muscle relaxation
9.	Switzerland	Bad Ragaz, Leukerbad, Scuol	Siliceous, thermal, bicarbonate	Osteochondrosis, nervous system, cardiovascular system
10	Georgia	Borjomi, Sairme, Nabeghlavi	Sodium bicarbonate, carbonated	Gastrointestinal system, kidney disorders, metabolic disorders

Note: The table was compiled by the author based on the textbook Resort Studies and Health Tourism: A Study Guide (A. S. Kuskov and O. V. Lysikova. — Rostov-on-Don: Phoenix, 2004. — 317 p.) and information obtained from Internet sources.

CONCLUSIONS



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The results of the study demonstrate that balneological mineral waters (springs), as natural resources, play an important role in the restoration and treatment of human health. Their therapeutic properties are determined by the degree of mineralization, ionic and salt composition, gaseous components, biologically active substances, temperature, and pH values. The history of mineral spring research dates back to ancient times and subsequently developed on a scientific basis with the advancement of hydrogeological, hydrochemical, laboratory, and cartographic research methods. Therefore, the comprehensive study of mineral waters provides an important scientific basis for assessing their natural characteristics, identifying patterns of spatial distribution, making effective use of their therapeutic potential, and ensuring their protection as natural resources.

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