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IN HEALTH TOURISM AND RESORT BUSINESS**

**Abstract.** *The article is devoted to the study of thermal springs as valuable natural resources. It examines in detail the relationship between geological processes (endogenous and exogenous) and the formation, distribution and chemical composition of underground mineral waters. Particular attention is paid to the role of magmatism, volcanism, tectonic movements, chemical and physical weathering of rocks, as well as karst processes in the creation of unique deposits of thermal waters. The author analyzes indicators of geological activity, such as seismic, volcanic and hydrothermal activity, as well as geochemical and geophysical indicators that allow us to understand the dynamics of the Earth and predict natural phenomena. Considerable attention is paid to the healing properties of thermal waters and their use in balneo-therapeutic practice for the treatment of various diseases. Separately, the potential of Ukraine in the use of geothermal resources is highlighted, in particular, significant reserves in the Carpathian region and Crimea, as well as in Poltava and Kharkiv regions are emphasized. Top 8 most famous thermal springs in Zakarpattia region are investigated. There are: Kosino Thermal Waters in Kosino, Zhayvoronok Health Complex in Beregove city, Thermal vats, Lumshory village, Teply Vody recreation complex in Velyatino village, Zolota Hora complex in Barvinok village, Karpatiya water park in Mukachevo city, Apartel Rikka Khust spa complex in Khust city, Derenivska Kupil Complex in Nizhne Solotvyno village. The prospects for the development of geothermal technologies in Ukraine and the features of the location of deposits are considered. The article emphasizes the importance of sustainable use of geothermal resources to prevent depletion and negative impact on the environment. It is noted that thermal springs are not only an object of nature management, but also a spatial phenomenon that requires dynamic monitoring. Taking into account the current situation in Ukraine, especially in Transcarpathia, thermal waters are considered an extremely important resource that requires proper geodetic monitoring to ensure the sustainable functioning of resort areas and preservation the natural balance.*

**Keywords:** geological processes, mineral waters, balneotherapy, sustainable use, geodetic monitoring.

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## **ТЕРМАЛЬНІ ВОДИ УКРАЇНИ: ПОТЕНЦІАЛ ВИКОРИСТАННЯ В ОЗДОРОВЧОМУ ТУРИЗМІ ТА КУРОРТНОМУ БІЗНЕСІ**

**Анотація.** Стаття присвячена вивченню термальних джерел як цінних природних ресурсів. У ній детально розглядається взаємозв'язок між геологічними процесами (ендогенними й екзогенними) та формуванням, поширенням і хімічним складом підземних мінеральних вод. Особлива увага приділяється ролі магматизму, вулканізму, тектонічних рухів, хімічного та фізичного вивітрювання гірських порід, а також карстових процесів у створенні унікальних родовищ термальних вод. Автори аналізують такі показники геологічної активності, як сейсмічна, вулканічна та гідротермальна активність, а також геохімічні та геофізичні показники, що дозволяють зрозуміти динаміку землі та прогнозувати природні явища. Значна увага приділяється цілющим властивостям термальних вод та їх використанню в бальнеотерапевтичній практиці для лікування різних захворювань. Особливо виділяється потенціал України у використанні геотермальних ресурсів, зокрема, наголошуються на значних їх запасах в Карпатському регіоні та в Криму, а також у Полтавській та Харківській областях. Досліджено 8 найвідоміших термальних джерел Закарпатської області. Це: термальні води Косино в селі Косино, оздоровчий комплекс Жайворонок у місті Берегове, термальні чани села Лумшори, рекреаційний комплекс Теплі Води в селі Велятино, комплекс Золота Гора в селі Барвінок, аквапарк Карпатія в місті Мукачево, спа-комплекс Apartel Rikka Khust у місті Хуст, комплекс Деренівська Купіль у селі Нижнє Солотвино. Розглянуто перспективи розвитку геотермальних технологій в Україні та особливості розташування родовищ. У статті наголошується на важливості сталого використання геотермальних ресурсів для запобігання виснаженню й негативному впливу їх експлуатації на навколишнє середовище. Зазначається, що термальні джерела є не лише об'єктом природокористування, а й просторовим явищем, яке потребує динамічного моніторингу. Враховуючи сучасну ситуацію в Україні, особливо на Закарпатті, термальні води вважаються надзвичайно важливим ресурсом, який потребує належного геодезичного моніторингу для забезпечення сталого функціонування курортних зон та збереження природного балансу.

**Ключові слова:** геологічні процеси, мінеральні води, бальнеотерапія, стале використання, геодезичний моніторинг.

**Formulation of the problem.** In the modern world, where the development of resort business, medical rehabilitation and sustainable nature management are high on the agenda, the availability of therapeutic thermal springs and the search for the ways to their best use are becoming particularly important. With this in mind studying the interrelationships between the complex geological processes that form underground mineral waters and the potential for their use in the resort business and balneology play an important role [1, 2].

As a number of resort and recreational areas in the eastern and southeastern parts of Ukraine

are currently under the temporary occupation, the role of its western regions, in particular Transcarpathia, in the balneological sphere is growing significantly. The uneven distribution and complexity of a number of hydrothermal water deposits in Ukraine carries the risk of their depletion and negative impact on the environment with intensive use of these deposits in balneology and resort business [3]. Therefore, research into the geological prerequisites for their occurrence and potential for the use in resort management and balneology is of a particular importance.

**Analysis of recent research and publications.** These issues are addressed by Khanas, U. Ya., Popyk, M. M., Lemko I. S., Kir-tich L. P., Zharnikova R. S., Fekishgazi B. M., Gabchak N., Gorbey S., Tsymbal O., and others.

The availability of thermal waters in a particular region is determined by the specifics of the geological structure of the territory and deep processes in the Earth's interior, in particular active volcanism, tectonic activity and geodynamics, which could contribute to the formation of a high-temperature thermal field. In addition to high temperatures in the Earth's interior, a prerequisite for the formation of thermal water deposits is the presence of reservoir rocks that prevent their migration [4].

The relationship between underground mineral water deposits and geological processes is very close and multilateral. Geological processes, both endogenous (internal) and exogenous (external), play a key role in the formation, distribution, and chemical composition of mineral waters [5].

**Identification of previously unresolved aspects of the problem.** The historical stages of thermal mineral water usage for spa and health improvement were unresolved previously. The analysis of interconnections between thermal mineral water deposits and geological processes was made previously without taking into account usage of thermal mineral water for health improvement. The classification of geothermal (thermal) waters was made without any attention to their usage in balneotherapy, spa medicine and hydrogeology. The research of thermal waters distribution in Ukraine was out of date and need to improve nowadays. The regulatory and legal framework for the functioning of resort system in Ukraine need to be optimized. The investigation of most popular destinations of medical and health tourism in Transcarpathia was out of date and need to be actual.

**Setting the task.** The purpose of the article is to present an integrative approach that effectively combines geological, morphological, technical, technological, economic, organizational, therapeutic, medical and rehabilitation aspects of the use of thermal waters in balneology and resort business. Although each of these aspects is studied separately, their comprehensive consideration, especially with a focus on the national potential, is important. The main task of this study is to summarize and systematize information about the location, conditions of occurrence

and exploitation, medical and rehabilitation characteristics and potential of thermal water deposits in Ukraine for their rational use in balneology and resort business, which is a fundamental problem for the development of effective strategies for medical rehabilitation and balneology. To achieve the goal, we suggest to solve the following tasks: – to investigate historical development of thermal mineral water usage for spa and health improvement; to analyze interconnections between thermal mineral water deposits and geological processes; to classify geothermal (thermal) waters used in balneotherapy, spa medicine and hydrogeology; – to investigate distribution of thermal waters in Ukraine; – to summarize the regulatory and legal framework for the functioning of resort system in Ukraine; – to identify the most popular destinations of medical and health tourism in Transcarpathia.

**Summary of the main research material.** Resort treatment with the use of geothermal waters has been known since ancient times: various buildings for hydrotherapy in places where hot mineral waters emerge were prototypes of modern balneological resorts. Information about the healing properties of the waters spread far beyond the areas where the springs were located. Hot mineral springs and other healing natural factors became the basis of the healing secrets of temples. Legends, architectural and artistic monuments reflect the use of thermal mineral waters by cult servants to perform rituals and, at the same time, to demonstrate the healing of the sick people. For example, the Rigveda, the oldest monument of Indian literature, contains information about 'sacred pools' at temples, into which sick people were immersed. The works of Chinese scientists also mention sources of hot healing waters. The Old and New Testaments mention the Pool of Siloam, the sacred lake of Bethesda near Jerusalem. Aristotle's works mention the use of thermal mineral waters for medicinal purposes in Ancient Greece; Plutarch testifies that the hot springs on the island of Euboea attracted sick people from the most remote areas. This is how the tradition of building accommodations for visitors in therapeutic areas came about [1].

The remains of capital structures at carbon dioxide water springs in the vicinity of the modern St. Moritz resort in Switzerland are among the most ancient material evidence of thermal water treatment dated back to the Bronze Age. Ruins of ancient spa facilities have been found in Greece. History provides numerous examples of

the Romans not only using mineral water treatment facilities that existed in the conquered territories but also borrowing the related religious cults. Ruins of these facilities from the Roman period are preserved in the area of the modern thermal balneological resorts of Beile Herculane and Sângeorz-Beu in Romania, Budapest (ancient Aquincum) and on the shores of Lake Balaton in Hungary, in the Varaždin Toplice and Dobrna resorts in the former Yugoslavia, in Hisarya in Bulgaria, Baden in Switzerland, Baden in Austria, Wiesbaden in Germany, Aix-les-Bains in France, Bath in Great Britain, near Timgad in Algeria and elsewhere. There were numerous resorts with mineral springs in Italy, especially in Lazio and on the coast of the Gulf of Naples. The resort of Baiiae (now Baia) with its terraced thermal baths was very popular. It was a favorite vacation spot for the Roman nobility thanks to its picturesque coastline and mineral springs; villas belonging to Marcius, Pompey, Caesar and others were located here. Virgil's Aeneid describes the thermal healing spring of Aquae Albule. During the empire, a grandiose balneological complex with a pool for 1,000 people and villas for aristocrats was created here. Emperors built luxuriously equipped baths in Rome on the sites of hot mineral springs. Therefore, it can be assumed

that thermal mineral waters were the natural factor contributing to the emergence of the first resorts. In the early Middle Ages, Plombières-les-Bains and Aachen were famous thermal resorts and favorite vacation spots of Emperor Charlemagne. Later, the mineral springs of Spa and Cotter became famous and the Abano Terme springs known in ancient times regained their glory (from the 13th century) [1].

Nowadays, geothermal waters are found all over the world, but their concentration is higher in areas with active tectonics and volcanism. Thus, balneological resorts with nitrogen-silicon thermal waters are common in the regions of predominantly Alpine folding: Tskhaltubo, Tsanchi (Georgia); Alma-Arasan (Kazakhstan); Issyk-Kul resort area, Issyk-Ata (Kyrgyzstan); Obi-Garm, Khoja-Obi-Garm (Tajikistan); Nalchik (Russia); Yevpatoria (Ukraine), Gorna Banya (Bulgaria), Coteaux (France) [1].

Geothermal waters are classified according to temperature, acidity, mineralization level and hardness. The variety of these indicators allows using these waters in various areas of balneotherapy and medical rehabilitation (Table 1).

Thermal waters have healing properties due to their high content of minerals and trace elements. They are used to treat diseases of the musculo-

Table 1

### Classification of geothermal (thermal) waters used in balneotherapy, spa medicine and hydrogeology

Criterion	Category	Value range	Balneotherapy/spa medicine significance
Water temperature (°C)	Cold	< 20 °C	Not considered thermal; limited use
	Subthermal	20–35 °C	Moderate therapeutic and health-improving effect
	Thermal	35–42 °C	Optimal for balneotherapy
	Hyperthermal	> 42 °C	Used after cooling
Acidity(pH)	Acidic	< 6,5	Limited use, dermatology
	Low acidic	6,5–6,9	Simulating effect
	Neutral	7,0–7,5	Most universal
	Alkaline	> 7,5	Gastrointestinal tract and skin diseases
Mineralization (g/l)	Very weak	< 1	Drinking treatment
	Weak	1–3	General health effect
	Moderate	3–10	Balneological treatment
	High	10–35	Limited topical use
	Saline	> 35	Specialized treatment
Hardness (mmol/l)	Very soft	< 1,5	Drinking treatment
	Soft	1,5–3	Universal use
	Moderate hardness	3–6	Use with caution
	Hard	6–9	Mostly topical use
	Very hard	> 9	Technical / specialized use

Source: developed by the authors using AI technology of ChatGPT

skeletal system, central and peripheral nervous systems, cardiovascular system, skin, respiratory organs, etc. Resorts and sanatoriums are created in the area of thermal springs. For example, resorts with siliceous thermal waters are recommended for patients with diseases of the musculoskeletal and nervous systems, vein diseases (phlebitis, thrombophlebitis in the residual stage), as well as occupational chronic heavy metal poisoning while hydrogen sulfide thermal resorts are good for patients with a number of gynecological and skin diseases [6].

Zakarpattia, Lviv, Odesa, Kherson as well as Poltava and Kharkiv regions are the most promising for the development of thermal balneological resorts in Ukraine. There are more than 30 deposits of almost all types of thermal waters in the Zakarpattia region. The water temperature at a depth of 2 km is  $+120^{\circ}\text{C}$ . The wells lift this water to the surface with temperatures of  $+20 - +61^{\circ}\text{C}$ . The Transcarpathian artesian basin consists of the Chop-Mukachevo and Solotvyno basins, separated by the Vygorlat-Gutyinsky range. It is the lithological and petrographic composition of the rocks that most influences the chemical composition of the mineral waters in this region [7].

The thermal waters whose mineralization varies from 0.35 to  $100\text{ g/dm}^3$  are found at a depth of 33 to 2050 m in the Transcarpathian region and are considered as the most promising. The most famous deposits of carbonated waters in this region are located in Uzhhorod (cold and thermal waters), Vyshkov (thermal), Shayan, Bushtyno (cold), Berehove (thermal), as well as springs in the area of the village of Velyka Dobron, the town of Chop and within the Vyshkovskyi ore field. The most famous resorts with carbon dioxide waters in Ukraine are Polyana, Svalyava, Soimy and Shayan [8].

Foothill depressions, platform depressions, intermountain depressions and depressions of ancient and young mountain fold region are the most favorable structures for the formation of sulfide thermal waters. These structures are very often have oil and gas deposits. Weakly sulfide thermal medicinal waters are developed in separate areas of the Transcarpathian depression. The largest deposit, Sinyak, is located on the slopes of the Vygorlat-Gutyinsky range within the development of Neogene volcanogenic rocks. Most of the sulphide water sources are located along the north-eastern edge of the Solotvyno Depression [9].

Siliceous thermal mineral waters are among the most common and valuable mineral waters in Ukraine. Silicon is a specific component in their composition and the main source of silicon is quartz and silicates [10, 11]. The diversity of the chemical composition of thermal waters specifies their wide range of uses in balneotherapy. Derenivska Kupil, Kosyno, Berehove, the Khust-Vynogradiv resort and recreation area are worth mentioning among the most prominent resort areas in this category of silicon thermal/subthermal waters. (Table 2).

Based on Article 1 of the Law of Ukraine On Resorts the above-mentioned destinations are included in the list of therapeutic and health resorts, as they have mineral and thermal waters good for treatment, medical rehabilitation and disease prevention [12].

Underground therapeutic thermal waters can also be used for industrial bottling. The procedure for granting access to such deposits is determined by the Code of Ukraine on Subsurface Resources and other acts of current legislation [13]. In accordance with Article 48 of the Land Code of Ukraine, sanitary (mining and sanitary) protection districts and zones are established in

Table 2

### Top 8 most famous thermal springs in Zakarpattia region

No	Name	Location
1	Kosino Thermal Waters	Koson village
2	Zhayvoronok Health Complex	Beregove city
3	Thermal vats	Lumshory village
4	Tepli Vody recreation complex	Velyatino village
5	Zolota Hora complex	Barvinok village
6	Karpatiya water park	Mukachevo city
7	Apartel Rikka Khust spa complex	Khust city
8	Derenivska Kupil Complex	Nizhne Solotvyno village

Source: composed by the author [16]

these territories [14]. A common feature of therapeutic and health resorts and thermal resorts is the presence of natural therapeutic resources that are officially recognized as suitable for treatment, medical rehabilitation and disease prevention. The lands of thermal resorts are built up with buildings and structures necessary for their operation, with infrastructure facilities used for treatment, medical rehabilitation, disease prevention and recreation [15]. Mineral waters and therapeutic muds, which are natural therapeutic resources, are extracted in volumes limited by the central executive authorities that implements state policy in the area of geological study and rational use of subsoil resources. The quality of natural therapeutic resources is regulated by a special medical (balneological) assessment specifying the composition of components beneficial or harmful to humans [12].

**Conclusions and prospects for further research.** The study found that thermal waters are not only an object of natural resource use, but also a spatial phenomenon that requires dynamic observation. Geodetic monitoring is a key tool in preserving the natural balance and providing the sustainable functioning of the resort areas. A comprehensive approach to the study of this resource covering the geological prerequisites for its formation, physical and chemical, medical, rehabilitation, health improving and balneological characteristics supports a conclusion of the strategic importance of using thermal waters in resort business and balneology. With the introduction of martial law in Ukraine, the role of the western regions in balneotherapy and medical rehabilitation has grown significantly. Therefore, the rational management of thermal water resources should be based on scientifically sound approaches that integrate geological research with medical rehabilitation, balneological resort and nature conservation strategies and health care needs.

Therefore, the results of the study confirm the feasibility of forming a unified national program for monitoring, preserving and effectively using thermal waters as one of the key resources for the sustainable development of resort system in Ukraine.

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