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**Archaeology
of Thermalism.
New studies
on healing waters**

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Archaeology of Thermalism. New studies on healing waters

edited by

Maddalena Bassani and Jacopo Tabolli



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Thermal Scientific Research and Therapies in the Euganean Area

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Thermalism, also referred to as balneotherapy or thermal therapy, encompasses the therapeutic use of various forms of water, such as hot springs, mineral baths, and mud baths, for the treatment and prevention of various medical conditions (for health and wellness benefits). The practice of immersing oneself in hot springs or thermal baths dates back to ancient civilizations, where natural thermal springs were revered for their healing properties. With advances in medical understanding and technology, the concept of thermalism has evolved into a recognized form of complementary and alternative medicine to incorporate a more scientific and holistic approach to health and well-being.

Thermalism in the Euganean region: an ancient history

Located in the northeast part of Italy, 50 km away from Venice, the Euganean Hills area is renowned for its abundant thermal springs, which have been recognized for their healing properties since pre-Roman times. The names of Abano and Montegrotto, two of the most popular destinations for hot springs in this area, seem to be primarily linked to the old tradition of thermalism in pre-Roman times. Attested by archaeological findings, Abano's origins are believed to go back to the 9th century BC, when ancient tribes living in the area used natural hot springs to perform rituals and recover from illness (Erfurt 2021). The nearby town of Montegrotto and its long tradition of hot spring use is another historical example, with the knowledge about the curative properties of the mineral-rich hot springs being placed as early as the Iron Age (onset circa 1380 BC).

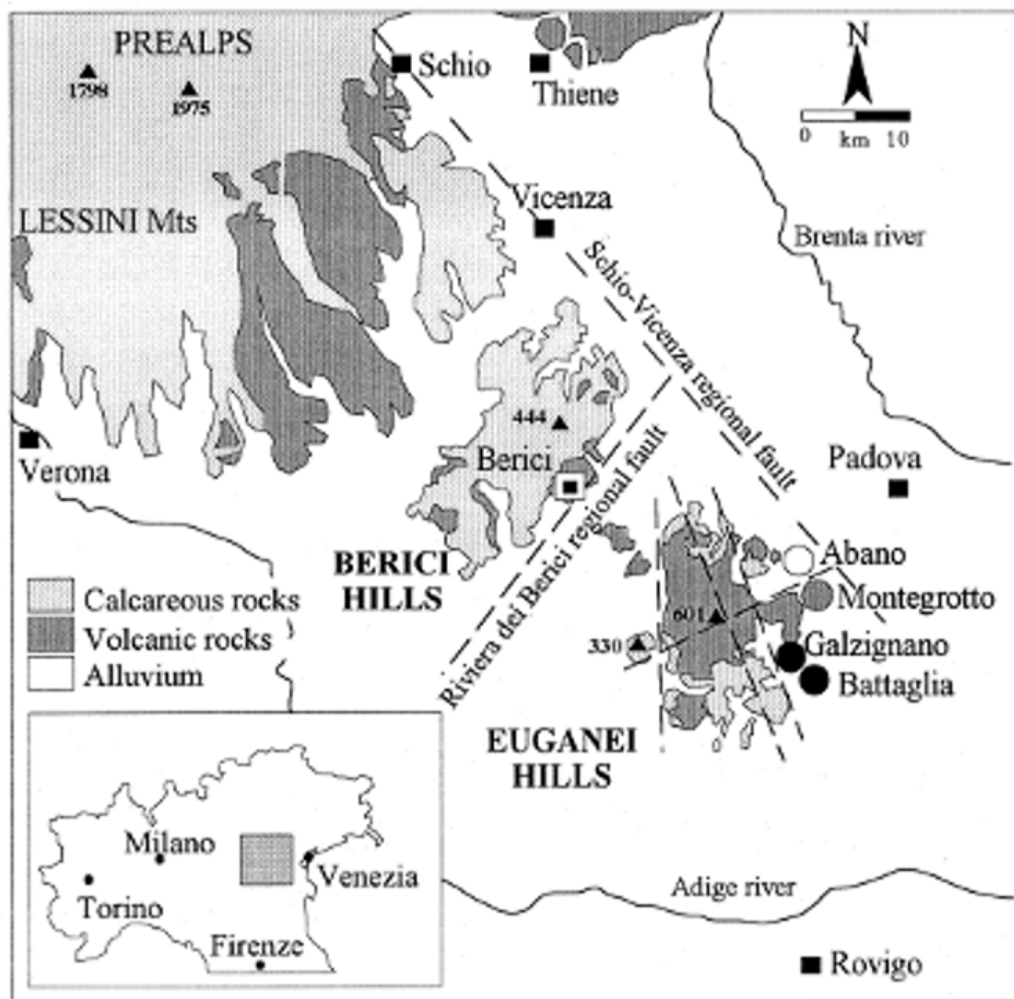
In Roman times, the Euganean region has long been recognized for the health benefits of its thermal waters, known as *Aquae patavinae*, as evidenced by archaeological remains of Roman thermal baths and historical references by writers like Livy and Pliny the Elder. The Romans built baths and spas around these thermal waters, which became popular destinations for relaxation and healing (see Bassani, Bressan, Ghedini 2012 with previous bibliography). The Romans certainly knew about the natural hot springs, as it is evidenced by the remains of an original Roman bathing complex, the *Terme Romanae*. This might explain the origin of the name Montegrotto, which, for tradition, is derived from the Latin *Mons Aegrotorum* and translates into "mountain of sick people". Claudius Claudianus, a Roman poet and senator of the 4th century AD, in a short poem recalls that by immersing oneself in the waters the suffering individual regains lost strength and returns to health. Additionally, some epigraphic texts have provided evidence of the deities believed to be responsible for the various thermal springs and

their purported healing and sacred properties. As a testament to the sacredness of the area of Colle Montirone in Abano, there is a high number of Roman glasses that Maria Paola Lavizzari Pedrazzini attributes to the presence of an emporium that provides containers for the sick devotees to draw and drink the healing thermal waters (Lavizzari Pedrazzini 1995). With the end of the Roman Empire, despite the economic difficulties that had caused its decline, the spa did not cease to exist, in fact it continued to be visited, no longer for fashion and pleasure, but for the waters. Even with the advent of Christianity, the beneficial and curative properties continued to be recognized.

During the Middle Ages, thermalism experienced a resurgence as monasteries and religious institutions began to develop spa facilities around the region's thermal springs. These spas became centers of health and wellness, attracting pilgrims and travellers seeking relief from various ailments. In the Renaissance period, the popularity of thermalism continued to grow, with prominent figures such as the Doge of Venice and members of the aristocracy patronizing thermal baths for both medical treatment and leisure. The renowned Renaissance physician and naturalist Pietro Andrea Mattioli also extolled the therapeutic virtues of the Veneto region's thermal waters in his writings. In more recent times, the waters of the Abano spas were recognized especially for their medicinal properties. A British traveller who visited Italy between 1663 and 1665 provided a vivid account of Monteortone's spring in Abano. He noted the presence of a fountain located a mile away from the Abano spas that was available for purchase in apothecaries' shops for drinking purposes. The demand for mineral waters may be attributed to the medical belief that each spring and spa possessed unique properties beneficial for treating various ailments and illnesses (Toffolon 2023). During the 18th and 19th centuries, thermalism experienced a golden age in the Veneto region, with the development of luxurious spa resorts and the emergence of medical tourism. Wealthy Europeans flocked to renowned spa towns such as Abano Terme, Montegrotto Terme to partake in hydrotherapy treatments and to socialize in the elegant surroundings. In the contemporary era, thermalism remains an integral part of the Veneto region's cultural heritage and tourism industry. The thermal spas continue to attract visitors from around the world, offering a wide range of treatments. Presently, the Euganean District boasts nearly 100 spas, making it one of the foremost centers for thermal baths and mud treatments globally, with approximately 1.8 million mud applications annually (Calderan et alii 2020).

The Euganean Geothermal Field and the curative properties of its waters and mud

The Euganean Hills represent the surviving remnants of ancient volcanic activity. The region's volcanic activity resulted in the formation of a variety of minerals and thermal springs. The volcanic rocks of the Euganean area have undergone hydrothermal alteration over time, a process that consists of the interaction of hot water with the rocks, resulting in alterations to their mineral composition. Consequently, the thermal waters that emerge from the springs are enriched with various minerals, including sulfur, calcium, and magnesium, which are believed to have therapeutic benefits. The Euganean Geothermal Field (EGF) is the predominant ther-



1 | Geographic localization of the Euganean thermal area (from Gherardi et alii 2000).

mal area in northern Italy, situated within the Veneto alluvial plain, southwest of Padua, and close to the northeastern edge of the Euganean Hills [Fig. 1].

The hills are composed of a variety of geological formations, including sedimentary rocks, volcanic deposits, and limestone. These geological formations play a crucial role in the hydrogeological conditions of the area, influencing the flow and composition of the thermal waters. Several studies and analyses have investigated the physical and chemical properties of the Euganean salso-bromo-iodic thermal waters. Available data indicate temperatures ranging from 60°C to 86°C, with a total dissolved solids concentration limit, a measure of the combined content of all inorganic and organic substances, of 6 g/L, primarily comprising 70%

chlorine and sodium, with secondary elements including calcium, magnesium, and potassium. The high temperature is another important factor in determining the therapeutic effects. Measurements of radioactive isotopes suggest a residence time exceeding 60 years, potentially extending to a few thousand years. Analyses reveal the meteoric origin of the thermal waters, which infiltrate an area up to 1500 meters above sea level (a.s.l.).

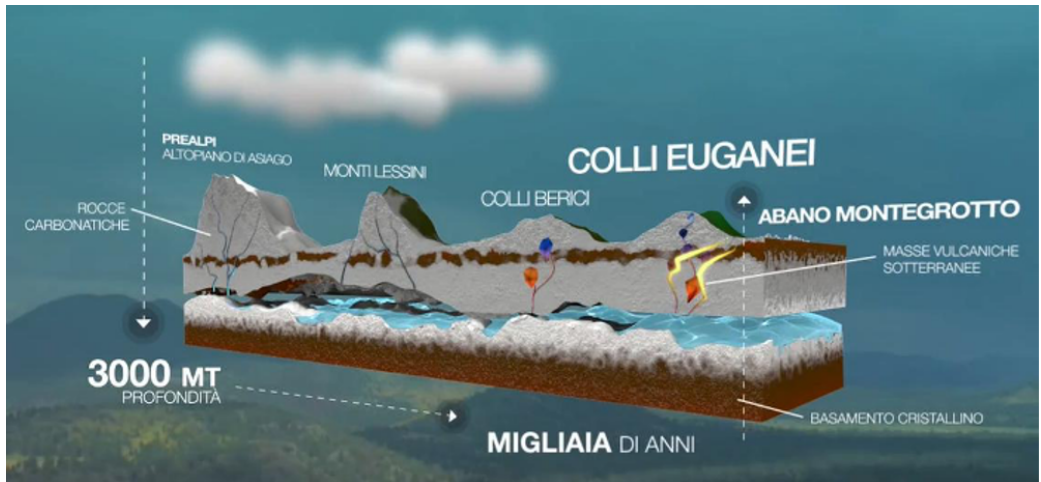
In the 1970s, a comprehensive study of the Euganean Hills and the EGF was conducted, which outlined the geological features of the district and proposed a straightforward conceptual model of the hydrothermal circuit (Piccoli *et alii* 1976). The Euganean groundwater originates from meteoric sources and infiltrates the Fore-Alps of the Veneto and Trentino Regions (NE Italy). It descends to a depth of approximately 3000 meters, where it warms due to the geothermal gradient, which is the increase in temperature as one goes deeper into the Earth. Fractures in the rocks facilitate the outflow of the thermal waters, warmed and enriched with minerals, particularly near the Euganean Hills [Fig. 2].

As with thermal waters, the therapeutic properties of thermal mud have long been known. Pelotherapy, a widely practiced method in spas worldwide, often involves the use of natural clay subjected to maturation procedures, enriching mineral substrates with organic compounds released by microorganisms (Carretero, Gomes, Tateo 2013; Carretero 2020; Calderan *et alii* 2020). While the therapeutic effects of mud therapy are generally attributed to mechanical, thermal, and chemical properties, only a few studies have examined the microbiota of peloids and its correlation with therapeutic activities.

Peloids are unique mixtures of muds or clays comprised of mineral and organic elements formed through geological, biological, chemical, and physical processes. Utilizing peloids, either through baths or packs has demonstrated beneficial effects in treating rheumatic disorders, osteoarthritis, skin conditions, and other ailments (Carretero 2020; Bellometti, Cecchetti, Galzigna 1997). This practice is widespread globally and has been utilized in Europe for two centuries. Typically, peloids in most spas are sourced from natural muds and clays extracted from local lakes or seas, then undergo a maturation period of up to two years in specialized ponds (Carretero 2020).

Euganean mud treatments, involving the direct application of warm mud onto patients' skin, are acknowledged by the Italian Health System as therapies for rheumatic diseases. Each spa in the region has its own hot thermal well and is responsible for independently preparing therapeutic peloids according to regional regulations (BUR, 2015). These regulations outline traditional Euganean mud maturation procedures necessary for obtaining "Mature Mud AOC" certification (DGR n. 857, 15/03/2010; BUR 2015). The maturation process, termed 'maturation', involves the use of 'virgin clay' collected from the bottom of the natural Lago della Costa thermal lake [Fig. 3], which is then laid in artificial ponds or tanks at the spas [Fig. 4].

Initially, the clay is moistened with thermal water at temperatures exceeding 55°C for a few days to eliminate undesirable micro-organisms, followed by continuous coverage with flowing



2 | Thermal water origin (from Centro Studi Termali Pietro d'Abano 2013).

water at around 40 °C for at least two months (BUR 2015). During this period, the growth of a microbial mat, primarily consisting of photosynthetic organisms, is observed, indicating proper mud maturation. Content analysis of a specific form of chlorophyll used in oxygenic photosynthesis, Chlorophyll 'a', is conventionally used for quality control of mud maturation (BUR 2015). Subsequently, the mature mud is combined with the thermal water, which has a temperature of approximately 60 °C, and left to stand for a period of between six and 24 hours. This process reduces the microbial load and maintains the fluidity of the product before its utilization in therapeutic applications. The Euganean district is a notable example of a region that has been the subject of extensive research in this field, and it is regarded as a benchmark for advancing knowledge in this intriguing area (Carretero 2020).

The development of green microbial mats on mature muds, unique to Euganean peloids, has been linked to the use of local natural 'virgin clay' and specific maturation processes. Mud maturation experiments comparing natural substrates with commercial ones have shown a significant difference in green microbial biofilm growth (Tolomio *et alii* 2004).

In 1789 Salvator Mandruzzato, as public professor at the baths of Albano and professor of pharmaceutical chemistry in Padua (a university chair established in 1797 by the Napoleonic regime), wrote in a reference text, renowned and valued for both its quality and scientific approach, that "certain plants thrive and grow within the Thermal waters of Abano, however, those that do not exceed 40 degrees of heat". An observation reported before in words but with a vivid image by Pliny the Elder in his *Historia Naturalis* ("*Patavinorum aquis calidis herbae virentes innascuntur*": Plin. nat. II, 227).

Only after the 20th century, the complete therapeutic potential of the organic component of thermal muds was fully understood. While some investigations have screened photosynthetic



3 | Lago della Costa, natural source of virgin clay (Courtesy: Centro Studi Termali Pietro d'Abano).

and non-photosynthetic microorganisms based on microscopy observations [Fig. 5-7], comprehensive characterizations of isolated cyanobacteria are more recent.

Studies on cyanobacterial species, highly prevalent extremophilic organisms inhabiting Euganean muds (Gris *et alii* 2020) and many other hot spring microbial mats worldwide, have demonstrated their ability to produce bioactive molecules. They are known for synthesizing a wide range of molecules that exhibit promising features, including antimicrobial and antioxidant properties. Of particular relevance is their anti-inflammatory activity, which is in line with the primary healthcare indication recognized by the National Health Service for local thermal waters and muds: the treatment of chronic joint diseases and inflammation of the upper and lower respiratory tract.

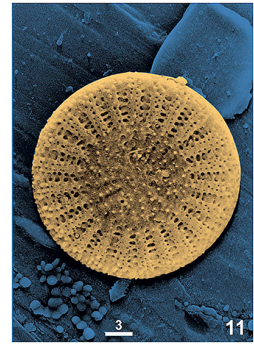
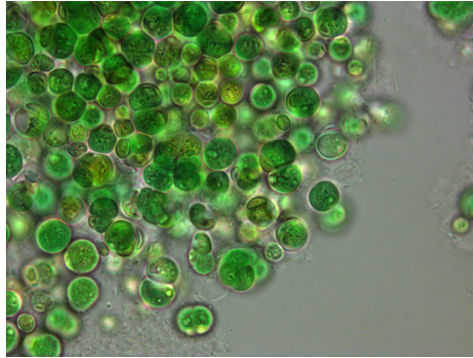
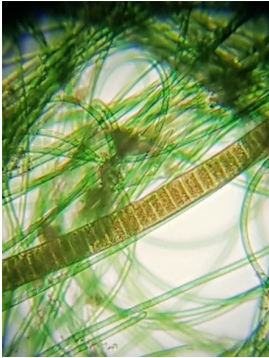
From a medical perspective, inflammation acts as a natural defense mechanism coordinated by inflammatory cells to safeguard the body against tissue injury and infection, while also restoring tissue balance. Triggered by inflammatory stimuli, these cells release pro-inflammatory mediators, or cytokines, which initiate and amplify the initial phase of the response. Typically, this phase is counteracted by the production of endogenous anti-inflammatory mol-



4 | Tank with mud in maturation (Courtesy: Centro Studi Termali Pietro d'Abano).

ecules, aimed at mitigating the severity and duration of the process. The recruitment of neutrophils and the peak of inflammation are followed by the resolution phase. Despite its protective role, prolonged and uncontrolled inflammation can lead to adverse effects, including extensive tissue damage, and may contribute to the development of various diseases such as rheumatic disorders, asthma, cancers, and cardiovascular conditions. In osteoarthritis (OA), the degenerative process results in gradual joint inflammation, breakdown of articular components, functional impairment, and pain. Conversely, prolonged use of synthetic anti-inflammatory drugs, such as cortisol analogs, can lead to undesirable side effects.

The exploration of the therapeutic properties found in high-value molecules produced by cyanobacteria thriving in the Euganean thermal muds is a crucial endeavour for scientifically validating the treatment of articular inflammation and uncovering new health-enhancing biomolecules. To date, research has confirmed the anti-inflammatory capabilities of lipids such as monogalactosyldiacylglycerol (MGDG) and digalactosyldiacylglycerol (DGDG), generated by *Phormidium* sp. ETS-05 (ETS, Euganean Thermal Springs) (Bruno *et alii* 2005; Ulivi *et alii* 2011).



5 | Cyanobacteria species at microscope (Courtesy: Centro Studi Termali Pietro d'Abano).

6 | Cyanobacteria species at microscope (Courtesy: Department of Biology, University of Padua).

7 | A diatom specie at microscope (Courtesy: Department of Biology, University of Padua).

The strain isolated from Euganean mature muds [Ceschi Berrini *et alii* 2004] is the most common species and is regarded as the primary focus for the maturation process. Its properties and lipidic composition have demonstrated sufficient effectiveness to obtain a European Patent confirming the therapeutic efficacy of the mud (EP1571203). Other biologically active compounds, polysaccharides, and complex heteropolymers have been extensively studied for their beneficial effects. Extracellular polymeric substances (EPS) represent polymers released by the microbial communities within biofilms. They form a highly hydrated gel, comprising around 98% water, which plays a crucial role in facilitating the formation of microorganism clusters. This gel enables various interactions among microorganisms, aids in resource capture, and enhances tolerance to environmental stress. Biofilms, depending on the ecological niche, can encompass both prokaryotic and eukaryotic microorganisms, such as archaea, bacteria, cyanobacteria, microalgae, and fungi. EPS released by bacteria and microalgae have been acknowledged for their antioxidant and anti-inflammatory properties [Zampieri *et alii* 2020; Zampieri *et alii* 2022; Zampieri, Caldara, La Rocca 2023; Caichiolo *et alii* 2024]. However, only a limited number of studies have delved into exploring these therapeutic attributes in cyanobacteria.

After 2020, the anti-inflammatory potential of polysaccharides directly extracted from Euganean therapeutic mud was investigated and their efficacy was validated through various inflammation models, encompassing morphometric analyses of the model organisms, assessment of immune cell recruitment, and analyses of inflammatory marker gene expression (Zampieri *et al.* 2020, 2022, 2023; Caichiolo 2024).

The intricacies of the microbiota biodiversity in spas, thermal mud, and the surrounding natural environment of the local thermal area remain inadequately delineated, including its potential for producing natural active compounds. The thermal springs of the Euganean Hills are not only characterised by their geological features but they are also often located in pic-

turesque natural settings. The surrounding lush vegetation and tranquil landscapes contribute to the overall therapeutic experience, promoting relaxation and stress relief.

Modern thermal treatments

The field of modern thermalism is concerned with the synergistic effects of heat, water, mud, and minerals on the body and mind. Thermal medicine in the Euganean region offers a wide range of treatments aimed at improving various health conditions. These treatments often involve immersing in thermal waters, mud baths, hydrotherapy, inhalation therapy, massages, and physiotherapy, and are typically carried out under the supervision of trained medical professionals, including doctors, physiotherapists, and spa therapists.

While numerous studies have investigated the efficacy of thermalism treatments for various health conditions, it is essential to note that the quality of evidence varies, and more high-quality randomized controlled trials are needed to confirm the therapeutic effects and mechanisms of action. Additionally, individual responses to thermalism treatments may vary, and factors such as water composition, treatment duration, and patient characteristics may influence outcomes. Overall, thermalism represents a promising complementary therapy for a range of health conditions, but further research is warranted to optimize its use in clinical practice. The following section will delineate the most significant conditions and disorders for which thermalism is indicated [Moros 2016].

Rheumatological Conditions: Research has shown that thermal baths can be beneficial for individuals suffering from rheumatological conditions such as rheumatoid arthritis and osteoarthritis. The warm water and mineral content of thermal springs can help to alleviate pain, reduce inflammation, and improve joint mobility. Studies have demonstrated improvements in pain scores, joint stiffness, and physical function in patients with these conditions after undergoing thermal treatments.

Dermatological Disorders: Thermal waters containing specific minerals such as sulfur and selenium have been found to have therapeutic effects on certain dermatological conditions. For example, sulfur-rich thermal baths have been shown to improve symptoms of psoriasis, eczema, and acne. The anti-inflammatory and antimicrobial properties of these minerals can help to soothe irritated skin, reduce itching, and promote healing.



8 | Male statue discovered in Montegrotto Terme in the 18th century possibly depicting a water deity (second half of 2nd century AD – Venice National Archeological Museum).

Respiratory Conditions: Inhalation therapy using thermal water vapour has been studied for its benefits in respiratory conditions such as chronic bronchitis, asthma, sinusitis, pharyngitis or laryngitis, vasomotor rhinopathy, otitis. The moist air can help to clear congestion and soothe irritated airways. The warm, moist air facilitates the opening of the airways, the thinning of mucus, and the improvement of respiratory function. Research has demonstrated improvements in symptoms and lung function in patients with these conditions following thermal inhalation therapy.

Chronic Pain Management: Thermal therapy may be a viable option for the management of chronic pain conditions such as fibromyalgia or neuropathy. Heat therapy can facilitate relaxation of muscles and improvement of flexibility, while cold therapy can provide temporary relief from pain by numbing the affected area.

Skin Conditions: The application of mineral-rich mud in a therapeutic context has been observed to exert exfoliating and moisturising effects on the skin. It has been demonstrated to be efficacious in the treatment of a number of dermatological conditions, including psoriasis, eczema, and acne, by its anti-inflammatory and healing properties.

Stress Reduction and Relaxation: Thermal spas are often associated with relaxation and stress reduction, which can have positive effects on mental health and well-being. Immersion in warm water has been shown to promote relaxation, reduce muscle tension, and alleviate stress and anxiety. Some studies have also suggested that thermal treatments may have antidepressant effects, although more research is needed in this area.

Rehabilitation and Recovery: Rehabilitation and recovery is a complex process encompassing a multitude of factors and stages. Thermalism is frequently employed as a component of rehabilitation programmes for individuals recuperating from injuries or surgical procedures. The buoyancy of water reduces the strain on joints and muscles, thereby facilitating gentle exercise and a more rapid recovery.

Sports Rehabilitation: Thermal therapy is a common component of the recovery regimen for athletes. Following intense training or competition, cold baths or ice baths are frequently employed to reduce muscle soreness and accelerate recovery. Another method of contrast therapy, which alternates between hot and cold treatments, may also be employed for similar purposes.

Other Conditions: gynecological diseases (e.g., pelvic connective sclerosis), Urinary system diseases (e.g., urinary tract stones), vascular diseases (e.g., sequelae of chronic phlebopathy or phlebitis, lower extremity varices), diseases of the gastrointestinal system (e.g., dyspepsia, irritable bowel).

In Italy, the National Healthcare Service (NHS) provides thermal treatments for patients suffering from various conditions, funded as part of the Essential Levels of Care (Livelli Essenziali di Assistenza, LEA). The treatments must be administered at a spa facility that is duly accredited

and affiliated with the National Health Service, and include a series of treatment cycles, as outlined below:

1. Mud or water baths (or showers) for arthreumatic diseases
2. Baths for dermatological diseases
3. Stoves or caves
4. Inhalation cures (inhalations, nebulizations, aerosols, humages)
5. Vaginal irrigations (cycle of 12 irrigations)
6. Rectal showers
7. Hydropinic cures for urinary tract stones
8. Hydropinic cures for diseases of the gastrointestinal system
9. Treatment for rhinogenic deafness, including:
 - ENT examination
 - Audiometry
 - Endotympanic insufflations
 - Inhalation cures
10. Integrated cycle of care for controlled pulmonary ventilation
12. Hydrofangobalneotherapy for liver detoxification, including:
 - mud baths
 - carbonated baths
 - hydropinic treatments

Conclusions

The combination of volcanic origin, ongoing geothermal activity, and hydrothermal alteration renders the Euganean Hills a distinctive geological area rich in thermal resources. The natural features have contributed to the development of spa towns and wellness resorts in the region, which have attracted visitors seeking relaxation, rejuvenation, and healing experiences. However, the past two decades have witnessed a decline in the number of spa guests, with the extent of this decline varying across different sectors. In particular, there has been a more pronounced decline in the number of spa guests with respiratory tract pathologies. Nevertheless, paradoxically, the number of chronic cases treated at the national level has been consistently on the rise. The causes of the decline in the number of treatments observed between the end of the last century and the first twenty years of the current century can be attributed to several factors. Firstly, there has been a question of the efficacy of thermal therapy. Secondly, there has been a decline in the prevalence of certain pathologies. Thirdly, there has been a failure of the therapeutic offer to evolve towards more promising areas. Fourthly, there has been a substitution of drugs. Fifthly, there has been a failure to teach thermal medicine in University Schools of Medicine.

Thermal treatments have been demonstrated to be an efficacious therapeutic means for alleviating the effects of disease, although they are typically not curative. It is often necessary to repeat the treatment every year, and this over long cycles. Nevertheless, the loyalty of spa guests is not in question, as numerous studies attest. Conversely, the challenge arises in re-

taining clients at the conclusion of the treatment cycle, as they are often replaced by younger individuals.

It is crucial to acknowledge that while thermalism may offer potential benefits for certain medical conditions, it should not be considered a substitute for conventional medical treatment. Individuals with specific health concerns should consult with their healthcare provider before incorporating thermal therapy into their treatment plan, particularly if they have underlying medical conditions or are taking medications that may interact with thermal treatments. Furthermore, the efficacy of thermalism may vary depending on factors such as the temperature and mineral content of the water, the duration and frequency of treatment, and individual response.

While there is some evidence supporting the therapeutic benefits of thermalism for certain health conditions, more robust scientific research is needed to validate its efficacy, safety, and specific applications. The lack of comprehensive evidence-based guidelines and protocols for thermalism treatments might deter healthcare professionals from incorporating them into their practice.

Addressing these challenges would require a multifaceted approach involving public education and awareness campaigns, investment in infrastructure and accessibility, regulatory reforms to ensure safety and quality standards, and continued research to establish the efficacy and best practices of thermalism medicine in the Veneto region.

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Abstract

Thermalism, also known as balneotherapy or thermal therapy, has been practiced for centuries across various cultures worldwide. The therapeutic benefits of thermal waters have been acknowledged since ancient times, and contemporary research continues to unveil its multifaceted healing properties. This paper provides an overview of thermalism medicine around the Euganean Hills of the Veneto region in Italy, elucidating its historical roots, physiological mechanisms, and therapeutic applications. Additionally, it discusses the current scientific evidence supporting the efficacy of thermal waters in treating various medical conditions, ranging from musculoskeletal disorders to dermatological ailments and stress-related disorders. Furthermore, it explores the potential mechanisms underlying these therapeutic effects, including the modulation of inflammation, pain perception, and stress response. Finally, this paper underscores the importance of further research to elucidate the precise mechanisms of action and optimize the therapeutic protocols of thermalism medicine for enhanced clinical outcomes.

keywords | Thermal water; Mud; Geothermal field; Euganean Hills; Thermal therapy.

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