Rocz Panstw Zakl Hig 2019;70(4):407-413

http://wydawnictwa.pzh.gov.pl/roczniki_pzh/

https://doi.org/10.32394/rpzh/2019.0093

REVIEW ARTICLE

NATURAL MEDICINAL RESOURCES AND THEIR THERAPEUTIC APPLICATIONS

Joanna Ziemska[1], Tomasz Szynal[1], Małgorzata Mazańska[1], Jolanta Solecka[1]

[1]National Institute of Public Health – National Institute of Hygiene,
Department of Environmental Health and Safety, 24 Chocimska str., 00-791 Warsaw, Poland

ABSTRACT

Natural medicinal resources are a country's natural wealth. Natural medicinal waters, medicinal gases, and peloids have many properties that enable their use in the treatment of gastrointestinal, circulatory, respiratory, bone and joint, and skin and soft tissue disorders. Balneotherapy can be also applicable in prevention of many diseases and rehabilitation. At present, because there are several chemicals of synthetic origin, there is a need to search for nonpharmacological approaches and explore natural healing sources, which better fit the human body. Compared to synthetic drugs, these resources rarely show side effects, which increases the comfort of therapy. The use of natural medicinal resources in the form of treatments in health resort medicine centers under the supervision of balneologists, combined with the healing properties of the climate, contributes not only to the reduction of treatment time for many diseases but also to improvement of therapy's results. The article discusses natural medicinal resources and some of their therapeutic applications.

Keywords: *natural medicinal waters, peloids, brines, balneology*

STRESZCZENIE

Uzdrowiskowe surowce lecznicze stanowią naturalne bogactwo danego kraju. Naturalne wody lecznicze, gazy lecznicze oraz peloidy mają wiele właściwości wykorzystywanych w terapii schorzeń układu pokarmowego, krążenia, oddechowego, kostno-stawowego, a także skóry i tkanek miękkich. Balneoterapia może mieć również zastosowanie w profilaktyce, jak i rehabilitacji wielu chorób. W porównaniu do leków syntetycznych, naturalne surowce lecznicze bardzo rzadko wykazują działania niepożądane, co zwiększa komfort i bezpieczeństwo terapii. Wykorzystanie naturalnych surowców leczniczych w postaci zabiegów w uzdrowiskach pod nadzorem lekarzy balneologów, w połączeniu z leczniczymi właściwościami klimatu, przyczynia się nie tylko do skrócenia czasu terapii, ale także do poprawy wyników leczenia wielu schorzeń. W artykule omówiono naturalne surowce lecznicze i ich niektóre terapeutyczne zastosowania.

Słowa kluczowe: *naturalne wody lecznicze, peloidy, solanki, balneologia*

INTRODUCTION

Balneological natural resources, which include natural medicinal waters (also named as healing waters or curative waters), natural gases, and peloids, are important elements of medical treatment and preventive physiotherapy worldwide [24]. Balneotherapy is a complex therapeutic intervention, which consists of various components including hydrothermal therapies, residential care in a specialized center (often called health resort medicine center), a beneficial climate, and rehabilitation and education of the patients [22]. Natural medicinal waters, gases and peloids can be used in different ways by internal and external application. The patients may either drink natural medicinal waters (crenotherapy); bath in natural medicinal water (hydrotherapy), peloids or gases; inhale natural gases; or have some peloid packs or tampons with peloids [13].

Natural medicinal sources such as waters and peloids can play an important role in therapeutic procedures of different systems. The use of water for medicinal treatment is probably as old as mankind. However, its popularity dropped with the development of effective analgesics and other synthetic medicines. Chemical drugs are reported to cause adverse reactions, including life-threatening ones [2]. At present, because there are several chemicals of synthetic origin, there is a need to search for nonpharmacological approaches and explore natural healing sources, which better fit the human body and cause less adverse effects.

Corresponding author: Joanna Ziemska, National Institute of Public Health – National Institute of Hygiene, Department of Environmental Health and Safety, 24 Chocimska str., 00-791 Warsaw, Poland, tel. +48 22 54 21 319, e-mail: jziemska@pzh.gov.pl

In this review, the authors describe the characteristics of chosen natural medicinal resources such as waters and peloids and provide their some therapeutic properties.

CHARACTERISTICS OF NATURAL MEDICINAL WATERS

In the past, various nomenclature and characteristics were used to describe natural medicinal waters and natural mineral waters. They were differentiated for the first time during the International Balneological Congress in Nauheim in 1911 with further changes in Salzuflen in 1934. The first European classification of medicinal waters defined them as natural waters with at least 1 g/l of dissolved minerals. Some of the medicinal waters were distinguished by minimum concentrations of components with a specific biochemical effect on the human body including for fluoride, sulfur (II) compounds, iodides, bromides, iron (II), arsenic, radon, and metasilicic acid (Table 1). These criteria still vary in different European countries owing to the lack of unambiguous clinical data for accepted specific substance concentrations, mainly regarding their pharmacodynamics and toxic properties as well as the local tradition of the country [16]. Compared with natural medicinal waters, natural mineral waters (bottled waters) are defined as food and their labeling has to abstain from anything that may be interpreted as medical advertising.

Table 1. Classification of medicinal waters according to the International Balneological Congress in Nauheim in 1911 with further changes in Salzuflen in 1934 and the Polish Ministry of Health Regulation from April 13, 2006 [16]

Specific water components (water type)	Minimum contents of water components according to the Nauheim/Salzuflen medicinal water classification	Minimum contents of water components according to the Polish classification of natural medicinal waters
Iodine J^- (iodide water)	1.0*/5.0*/10.0* mg/l	1.0 mg/l
Bromine Br^- (bromide water)	5.0/25.0 mg/l	-
Fluoride F^- (fluoride water)	2.0/20.0 mg/l	2.0 mg/l
Ferrum Fe^{2+} (ferric water)	10.0/20.0 mg/l	10.0 mg/l
Metasilicic acid H_2SiO_3 (metasilicic water)	50.0*/75.0*/100.0* mg/l	70.0 mg/l
Arsenic As(III) (arsenic water)	0.2/0.7 mg/l	-
Boric acid HBO_2 (boric water)	5.0/50.0 mg/l	-
Sulfur S^{2-} (sulfide water)	1.0/10.0 mg/l	1.0 mg/l
Radon Rn (radon water)	1/100 nCi	2nCi
Temperature (thermal water)	20°C	20°C
Carbon dioxide (CO_2) (carbonic acid water)	-	250 mg/l
	-	1000 mg/l

*Minimum contents of water components in various European countries.

From a balneological point of view, natural medicinal water is subterranean water that is chemically pure and exhibits slight fluctuations in chemical and physical properties [24]. Its composition depends on the type and structure of the rocks with which it comes into contact, hydrogeochemical processes (such as sorption, oxidation and reduction, leaching, weathering, hydrolysis), and physical parameters (temperature, pressure) and others [6]. The main criteria in the assessment of these waters are not only the confirmation of their original chemical and microbiological purity and quality but also their beneficial effects on human health.

The current Polish version of the classification of natural medicinal waters includes the actual research data on the properties of water elements (e.g. arsenic and boron) that can be potentially harmful to human health and therefore does not mention those elements as specific ones. According to the basic criteria of balneochemical classification, natural medicinal waters are classified as mineral medicinal waters (waters containing more than 1 g/l of dissolved mineral components), low-mineralized medicinal waters (waters containing less than 1 g/l of dissolved components, but distinguished by the content of one or several specific components at a concentration that exert pharmacodynamic effects), and mineral specific medicinal waters (waters meeting the criteria for mineral water and specific water) [17].

The content and type of minerals in a given medicinal water depend on local geological conditions. In groundwater, which is of natural origin, more than 50 elements of the periodic table were determined, which were divided into macronutrients, rare elements, and trace elements. The dominating macronutrients in groundwater include sodium, potassium, calcium, magnesium, chlorides, sulfates, and bicarbonates [17].

Sodium has a high waterbinding capacity, and together with carbonates and bicarbonates, it constitutes an alkaline reserve of the body. For per os use, water with a sodium content usually not exceeding 1 g/l is used. Sodium chloride saline waters up to 15 g/l and brine (15–50 g/l) are mainly used for bathing and after dilution for inhalation.

Calcium is found in medicinal waters mainly in combination with bicarbonates or chlorides. At a concentration of 500–700 mg/l, calcium is found in bicarbonate–calcium–magnesium waters. These waters supplement the body's need for calcium and magnesium and normalize heart function. At higher concentrations of about 1000–7800 mg/l, calcium is present in brine as calcium chloride. Waters of this type are mainly useful for bathing and in appropriate concentrations for inhalation and rinsing of body cavities. Magnesium is co-present with calcium in medicinal groundwater, but in concentrations generally lower than calcium (by about 50%). Magnesium participates in many enzymatic reactions, reduces myocardial sensitivity to hypoxia, has anti-arrhythmic properties, regulates blood pressure, and reduces nerve tension [26].

In addition to sodium, chlorides are the main component of sodium chloride waters, and their content in water reaches up to several dozen grams per liter (brines). The effects of chlorides on the body during bath (osmotic) or inhalation (increasing the secretion and fluidity of mucus) are because of their reaction with sodium ions [17]. Brines are concentrated salt (sodium chloride waters) solutions, which occur widely in natural forms such as coastal lagoons, salt or soda lakes, deep-sea brines, groundwater, and salterns or saltworks of anthropogenic origin [14]. A graduation tower is a unique structure that is used to produce salt; it removes water from a saline solution by evaporation, thereby increasing the concentration of mineral salts. It is constructed using natural materials (usually wood, branches of blackthorn). Effective brine concentrations are 5–7% solutions with sodium chloride as the main constituent. Other elements present in lower concentrations are calcium, magnesium, and potassium chloride. Inhalation with the use of the salt aerosol formed on brine graduation towers is one of the methods used in the treatment of respiratory diseases [8].

Sulfur (II) compounds occur in medicinal waters as hydrogen sulfide, sulfides, and bisulfides (depending on the pH of the water) and have keratolytic, keratoplastic, and bactericidal effects on the skin. Because hydrogen sulfide and sulfides bind heavy metals, they detoxify and desensitize when administered per os.

Sulphates (VI) occur in groundwater in combination with calcium, sodium, and magnesium. Waters containing significant amounts of magnesium sulfate are barely absorbed by the intestine and have a laxative effect after per os administration [17, 26].

CHARACTERISTICS OF PELOIDS

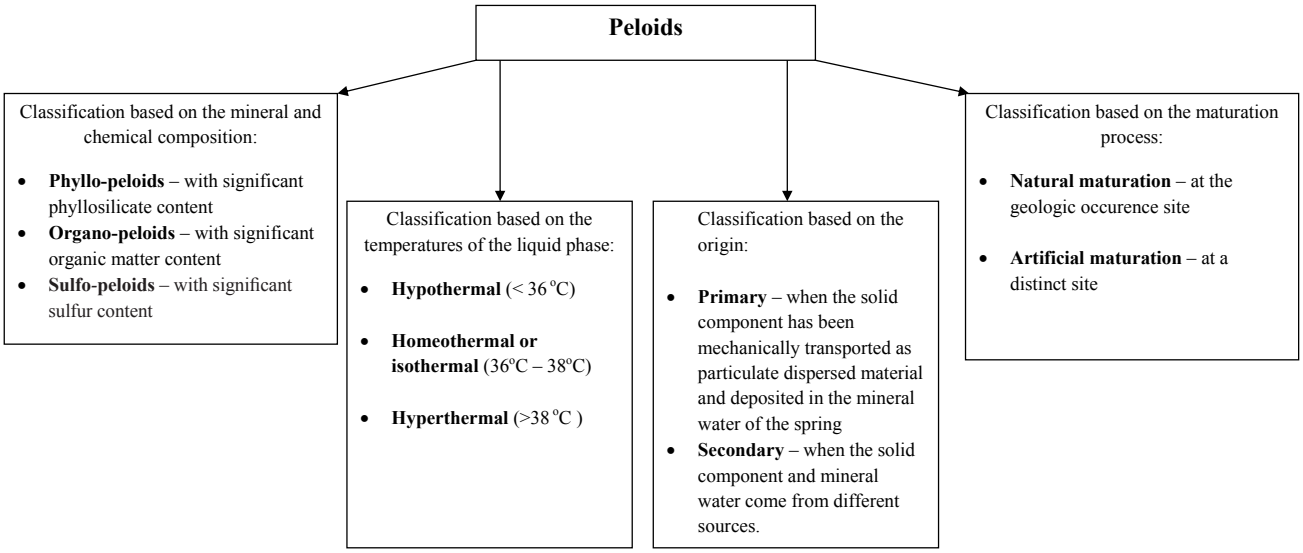
Peloids consist of humus and minerals formed over a very long period of time by physical, chemical, biological, and geological processes [3]. The properties of peloids also depend on the humified material and the regional rock.

One of the first definitions of peloids was established by *Lewis* [18] in 1933. According to him, peloid was any natural product composed of a uniform mixture of finely divided organic and inorganic matter with water and applicable in medical practice as cataplasm for external treatment.

Peloids can be classified based on their mineral and chemical composition (phyllo-peloids, organo-peloids, sulfo-peloids), temperature of their liquid phase (hypothermal, homeothermal or isothermal, hyperthermal), their maturation process (natural, artificial), and their origin (primary, secondary) [12]. The classification of peloids is presented in Scheme 1. Peloids can also be classified into eupeloids (original, undressed), parapeloids (crushed, milled, dressed), and peloids apogones (peloidic substances produced by adding liquid carriers). Based on the applications and properties of peloids, we can distinguish them into medical and cosmetic peloids. Medical peloids are recognized and evaluated by proper national authorities, which indicate their possible therapeutic applications. Medical peloids can be applied under medical prescription and supervision. Cosmetic peloids can be used in cosmetology and dermocosmetics as moisturizers, cleansers, and anti-wrinkle or anti-cellulite factors [12].

Therapeutic effects of peloids include stimulatory, antiphlogistic, and analgesic activities. In the maturation process of peloids with high organic content, new bioactive compounds can be biosynthesized by microorganisms. Fangotherapy is usually used to treat rheumatic diseases (arthrosis, arthritis, and fibromyalgia) and skin diseases (acne, psoriasis, and seborrhea). The term "fango," which originated in Italy, means the mud deposited from the thermal springs of sulfur-bearing sulfurous or sulfated water.

Another natural resource is named gyttja (also known as "nekron" mud, sapropel, or dy). Gyttja is a Swedish term for organic-rich freshwater mud, which is a mixed organic-rich mud that is rapidly accumulated in eutrophic lakes; the organic component that makes up to 40% of the dry mass results from the partially anaerobic putrefaction of plankton. It is a unique geological formation occurring at the bottom of water bodies (mostly in overgrowing, eutrophic lakes) [28]. According to *Korde* [15], gyttja contains not less than 15% and up to 90% of organic matter. However, gyttja is also known for its high mineral content. For example, in gyttja samples derived from lakes of eastern Latvia, minerals such as Ca, Fe, Mg, K, Mn, Na, Zn, and Ba were detected at concentrations above 50 mg/kg [28]. Sr, Cu, Cr, Ni, Pb, V, As, Co, Rb, Li, Se, and Cd were found at concentrations below 50 mg/kg. Because metal elements are incorporated in organic substances, it is important to evaluate the concentration of potentially toxic microelements such as As, Cd, Cr, and Pb [28].



Scheme 1. Classification of peloids

Depending on the origin, sediments can be classified as gyttja attributed to autochthonous sediments and dy attributed to allochthonous sediments.

Pelotherapy, which is a term usually used in southern and central European countries, is defined as the external application of peloids in both therapeutic and skin care indications.

THERAPEUTIC PROPERTIES OF NATURAL MEDICINAL RESOURCES

There are numerous therapeutic effects of natural medicinal waters and peloids. Bicarbonate mineral waters demonstrate positive effects on the digestive tract. Their consumption may neutralize acid secretion, increase the pH level in the gastric lumen, accelerate gastric emptying, and stimulate the release of digestive hormones. Bicarbonate waters create an alkaline environment and decrease bone resorption. They also have some benefits in reducing total cholesterol, LDL cholesterol, and fasting glucose [23].

Sulfate mineral waters are characterized by the presence of sulfate anions with different cations. Magnesium sulfate and sodium sulfate mineral waters have beneficial effects in the treatment of gastrointestinal disorders such as constipation. They improve bowel movements and stool consistency. Chloride waters contain chloride as the predominant element and sodium, calcium, and magnesium as the most abundant ones.

There are a few key therapeutic directions in which natural medicinal waters and peloids are successfully applied. Balneological treatments in health resort medicine centers are one of the most commonly used nonpharmacological approaches for rheumatologic diseases. The mechanisms by which immersion in medicinal or thermal water or the application of mud alleviates suffering in rheumatic diseases are not fully understood. The overall benefit is probably the result of the combination of various factors, mostly mechanical, thermal, and chemical effects. Baths in thermal water may influence muscle tone and pain intensity and may help to reduce muscle spasm and to increase the pain threshold. Mud-bath therapy increases plasma β-endorphin levels and secretion of corticotrophin, cortisol, growth hormone, and prolactin. Thermal mud-pack therapy reduces the circulating levels of important mediators of inflammation and pain, such as prostaglandin E2 (PGE2), leukotriene B4 (LTB4), interleukin-1 β (IL-1β), and tumor necrosis factor-α (TNF-α) [9].

Balneotherapy has also been proved to have beneficial effects on patients with osteoarthritis. Osteoarthritis is a degenerative musculoskeletal disease and leading cause of pain, disability, and impaired quality of life [4,10,11]. It affects synovial joints (mainly hips and knees), in which cartilage destruction, subchondral bone remodeling, osteophyte formation, and synovial inflammation are found, thereby leading to joint stiffness [11]. Osteoarthritis usually affects approximately 10% of people over 60 years of age [10]. Different clinical trials were conducted to evaluate the effectiveness of balneotherapy in patients with osteoarthritis. In one such study conducted by Branco et al., patients of both genders aged 64.8±8.9 years were diagnosed with osteoarthritis of the knee. They were randomized into three groups: sulfurous water (SW) group (47 patients), nonsulfurous water (NSW) group (50 patients), and control group (43 patients). Patients in the SW and NSW groups received a 10-week treatment consisting of 30 individual thermal baths (three baths a week, each bath lasting 20 minutes) in either sulfurous water or nonsulfurous water (tap water) at temperatures ranging from 37°C to 39°C. The patients in the con-

trol group did not receive any treatment. The results showed that at the end of treatment, hot SW baths were effective in reducing pain during movement, and their overall effects lasted longer than those of heated NSW baths [4]. In another clinical study, 42 patients (aged ≥ 60 years) diagnosed with knee osteoarthritis received mud therapy for 10 days. Mud therapy included the whole-body application of the combination of mineral medicinal water (with bicarbonate and calcium as predominant ions) and mud, which consisted mainly of silt, clay, sand, phyllosilicates, quartz, and calcite. The results showed that mud therapy significantly improved osteoarthritis-related pain, stiffness, and physical function. It also increased knee flexion and extension angle [11].

Balneotherapy has short- and long-term effects on patients with low back pain-another noninflammatory musculoskeletal disease. In a study by *Balogh* et al., a group of 60 patients with low back pain were assigned to balneotherapy and control groups. Balneotherapy was provided in the form of 30-minute baths in tubs filled with warm water (36°C), 6 days per week, for a total of 12 sessions in 15 consecutive days. The same procedures were applied to the control group with tap water as a placebo. Water used in balneotherapy was natural sulfur water with 2.4 mg/l S^{2-} concentration containing relatively high amounts of metasilicic acid (37 mg/l). Clinical improvements were found in the group of patients treated with balneotherapy and persisted for 3 months after the therapy [1].

As balneotherapy has been proved to be effective in the treatment of chronic pain, a randomized clinical trial on patients with fibromyalgia was designed and conducted. Fibromyalgia is a syndrome characterized by generalized skeletal muscle pain accompanied by diverse symptoms, such as fatigue, sleep disturbance, and anxiety/depression. In the study by Pérez-Fernández, a sample of 50 patients was divided into group A and group B. In phase 1, the patients in group A took 14 baths, 30-minute long, for a month, in bicarbonate sodium water of medium mineralization, alkalinity, lithic content, fluorine content, and silicate content at a temperature of 38°C in As Burgas, (Ourense), a thermal and public pool, and underwent the treatment prescribed by their doctor. Group B was treated only with the pharmacological treatment prescribed by their doctor. In phase 2, the groups were crossed. Immersion in mineral medicinal water caused a significant improvement in the impact caused by fibromyalgia. Balneotherapy has been proved to cause physiological effects both locally and generally, exerted by physical, chemical, and biological mechanisms. Hydrostatic pressure caused by thermal baths can produce analgesia. Bathing in mineral medicinal water can reduce certain mediators of inflammation, and this may be because of the presence of chemical components in the water [21].

Sulfurous medicinal waters have been used in medical hydrology as treatment for skin, respiratory, and musculoskeletal disorders [5]. Sulphur-rich water is effective in the treatment of dermatological disorders. The sulfur that penetrates the skin is oxidized and induces various physiological responses in the skin, such as vasodilation in microcirculation, analgesic influence on the pain receptors, and inhibition of the immune response. Sulfur also interacts with oxygen radicals present in deeper layers of the epidermis, producing sulfur and disulfur hydrogen, which may be transformed to pentathionic acid and may serve as the source of antibacterial and antifungal activities of sulfur water [20]. Moreover, if sulfurous medicinal water is applied to the skin in the form of maturated mud or peloid, its effect may be potentiated. The beneficial effects of sulfurous waters and sulfurous mud have been attributed to the presence of sulfur mainly in the form of hydrogen sulfide (H_2S). This form is largely available at acidic pH.

Subterraneotherapy is based on exposing patients to the synergic effects of physical, chemical, and biological stimuli present in underground excavations such as Wieliczka salt mine [19]. Its microclimate affects the whole organism stimuli and has a local effect in the respiratory tract as it isolates it from allergens, irritants, and harmful substances. High concentration of natrium chloride present in the underground aerosol stimulates the motor and secretory function of the respiratory tract epithelium, thus improving its cleaning and moisturizing effects [25].

CONCLUSION

Balneotherapy is officially recognized in many countries such as Italy, France, Spain, Hungary, Poland, Germany and Russia and is dependent on some specific geological, geographic, and meteorological preconditions [13]. The therapeutic activity of natural medicinal resources such as natural medicinal waters and peloids is widely known. In many disorders such as chronic pain, the use of balneotherapy is a safe therapeutic option with little adverse reactions and is usually well tolerated by patients; moreover, it provides analgesic, sedative, and muscular rejuvenative effects, which are quite important to achieve relief from these disorders. However, there are still not too many clinical studies to explain the mode of action of natural resources. *Varga* [27] explained that the therapeutic activity of these natural resources is linked with the inorganic content of water, brines, and peloids. However, he assumed that many experimental balneological studies were not designed properly, and they needed more treated groups, including negative controls. Reflecting the effects of balneotherapy in health resort medicine, it is important to consider other

environmental factors. The final therapeutic effect on the patient is the combination of many factors, such as the use of natural medicinal resources (hydrotherapy, pelotherapy), climate, outdoor activities, diet, health education, psychotherapy, and/or physiotherapy.

Acknowledgments

The authors kindly thank Dr Teresa Latour, a national expert in the field of natural medicinal sources, for her support and supervision. This work was financially supported by the National Institute of Public Health National Institute of Hygiene in Warsaw, Poland, in the frame of project No. BK-1, 2019.

Conflict of interest

The authors declare no conflict of interest.

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Received: 02.11.2019
Accepted: 01.12.2019