Review article

Thermal water – more than water!

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Abstract: *The use of thermal waters both for external use and for consumption is presented. Nowadays, the use of ecological products of natural origin is promoted, allowing for a significant improvement in the psycho-physical condition of users. Research is carried out to create natural products that comprehensively improve not only the condition of the skin, but the entire body of the user. Thanks to the development of modern technologies used both in cosmetics and other industries, it is possible to effectively use the composition and properties of thermal waters.*

Keywords: *cosmetics; thermal waters; health; dermocosmetics; geothermal waters.*

Thermal waters – definition, classification

Water covers 71% of the surface, including as much as 31.4% [1] located below the Earth's surface. This category includes both underwater reservoirs and water found in rock crevices. Thermal waters are indicated as an element of a wider category of groundwater, however, unlike the vast majority of them, their temperature exceeds the average ambient temperature. In some countries, a temperature limit has been set, beyond which water is considered thermal. In Poland, all waters exceeding 20°C are considered thermal waters. In the United States, thermal water can only be considered when its temperature exceeds 21°C, and in France it exceeds the average annual temperature in a given area by several degrees [1]. The temperature of thermal waters is directly dependent on the environment in which they occur. Thermal waters located extremely deep or located in regions with increased volcanic activity, their temperature is significantly higher than the springs located close to the earth's surface.

In 2011, a new geological and mining law was passed, which defined thermal waters as "groundwater, which at the outflow from the intake has a temperature of not less than 20°C" [2]. It is assumed that with an increase in the depth of water by 35 meters, its temperature increases by 1°C. The greater the depth, i.e. the smaller the distance to the earth's core, the higher the water temperature. Therefore, in some countries, e.g. in Japan, the temperature of thermal waters is even several dozen degrees and is used, among others, for the production

of geothermal energy. Thermal waters get underground thanks to the action of gravity and use the permeability of rocks. Depending on the relief, the water areas are at different depths:

- Climates of the area – size
- Existence of surface waters – lakes and rivers;
- The type and arrangement of the ground rocks – different permeability of different types of substrate [3].

In order for groundwater to exist, it is necessary to have a process such as infiltration, i.e. water infiltration. It is thanks to this process that the water present on the surface penetrates deep into the substrate and finally reaches the underground reservoir. The division of groundwater [4] takes into account such criteria as the depth of deposition, as well as the origin of these waters and the temperature. Additionally, mineralization is taken into account, and even the location in relation to the landforms or the force causing their flow to the surface. The groundwater typology with regard to the temperature criterion allows for the specification of the following types of water:

- cold water – the temperature is below 20°C;
- hot springs – thermal, the temperature is in the range of 20-36.6°C;
- hot water – temperature from 36.6 to 42°C;
- very hot water – temperature above 42°C.

Other divisions, where groundwater mineralization was taken into account, where the criterion of "sweetness" and presence were used mineral compounds. Due to the sweetness of the waters, the following were distinguished [5]:

- ultra-sweet – less than 0.1g of mineral substances dissolved in 1 dm^3 of water;
- fresh water - mineralization level in the range of 0.1-0.5 g/dm^3;
- akratopega [6] (slightly mineralized waters) – mineralization is 0.5-1.0 g/dm^3;
- mineral – the content of minerals is > 1.0 g / dm^3.

An additional classification of thermal waters is based on the origin of the water [7]:

- volcanic – its composition is unique, which results from the filtration process of rainwater that seeps through the volcanic rocks. Contains high concentrations of minerals and trace elements;
- thermal – warm mineral water. Its temperature is above 20°C and its composition differs from drinking mineral water in the concentration of chemical components;
- mineral – naturally mineralized water, characterized by a stable mineral content;
- spring – underground water, suitable for drinking after being collected. Unlike mineral waters, spring water does not have to contain a stable mineral composition.

The occurrence of thermal water in the world and in Poland

Typology taking into account geological conditions related to the occurrence of thermal waters are:

- slotted;
- stepped;
- karst spikes;
- layered.

The occurrence of thermal waters is determined by the presence of areas of deep tectonic dislocations, as well as areas of young volcanism. In extreme cases, the water temperature in such springs can reach 100ºC – thermal waters in the Aeolian Islands located in the Tyrrhenian Sea. The Hamman springs in Algeria are slightly "cooler", where the water temperature is "only" 95ºC. In contrast, thermal flows in Italy – Albano, Pisciarelli, have a temperature of 84ºC. Rabbitkattle in Canada and Thermopolis – Wyoming, where the water temperature is 70ºC, are also slightly cooler. The largest number of thermal springs is located in Japan – over 12.000. Both in Japan and in other regions of the world, thermal waters are used not only by people but also animals. The best example of such interspecific use of hot water pools are thermal springs located in Nagano Prefecture in Japan, where in the so-called In the Hellenic Valley, Macaques also use thermal springs.

Both in terms of health and relaxation, thermal waters were already used in the times of Ancient Rome. Sources say that both the Romans and the Japanese used such sources more than 1000 years ago. This type of water was used to prepare meals. At the beginning of the 20th century, the idea of using thermal sources to produce electricity appeared. The first attempts were made in 1904 in Italy, while already in 1913 in Caradello the first power plant with a capacity of 250 kW was built, which at the end of the 1940s reached a capacity of 130 MW [8]. Another facility of this kind was built in the Antipodes of New Zealand in 1955. A 47 MW geothermal power plant was built in Wairakei.

Geysers are a specific type of thermal springs. These geological formations throw out water that is more or less overheated, and most often it is steam. Although this form of groundwater runoff has been recorded for over 300 years, it still arouses interest and admiration. The efficiency of geysers is varied and may range from 0.1 to over 100 dm^3/s. The height of the ejected water column is very variable: from a few centimeters to 160 m, the largest 65 meters. Geysers are always found in areas that are tectonically active, particularly where magma hotspots are located shallow below the Earth's surface, providing heat that then warms underground water-filled reservoirs. In these formations, due to the extremely high pressure, the boiling point of the water in them exceeds 100°C, and sometimes it reaches the temperature of 120°C. The result is that when the boiling point is reached, the water rapidly turns into steam. This water then trickles down back into the underground chambers and the process repeats itself.

When analysing the issues related to this specific form of thermal waters, it is worth noting that in 1904 one of the New Zealand geysers – Waimangu, over a period of almost 4 years, ejected over 800 m^3 of a mixture of water, sludge and stones, and the height of some eruptions even reached 160 m Nowadays, the geyser is characterized by a significant decrease in activity, which is the result of an artificially lowered water table in the neighbouring Tarawera Lake. A similar procedure, limiting the scale of activity, was carried out on a geyser called "the father of all geysers", ie the Icelandic Great Geyser [9]. The most famous geysers are found in Iceland, in Russia – in Kamchatka, in the USA in Yellowstone Park and in New Zealand.

Thermal springs, apart from the undoubtedly variable chemical properties, as well as the ability to generate geothermal energy used later, for example for heating houses – Iceland, are also places of high biodiversity. Within them, we meet both hydrophilic and hygrophilous plants. In addition, a specific microclimate is created, which makes these ecosystems distinct, which makes them a habitat for many rare, and often even endemic and relict plants and animals. One of the best known and oldest thermal springs is the Blue Lagoon located in Iceland, which was entered by National Geographic on the list of 25 wonders of the world [10]. Due to the geological characteristics of this area, there are large deposits of magma at a relatively shallow depth. As a result, thermal springs in Iceland are classified as very hot, and the water temperature exceeds 42°C. The water present in thermal pools is a mixture of salt sea water and groundwater. The mineralization of the thermal waters of the blue lagoon is 26 g/l. The composition of the water is characterized by a high content of silica and sulfur compounds, which makes this place a popular destination for people suffering from various types of dermatoses.

Hungary has the world's largest geothermal lake. The presence of the lake in this area of Europe is related to the fact that this country is located in the area of a geothermal anomaly associated with the formation of the Pannonian Basin in the early and middle Miocene, which resulted in the stretching and thinning of the Earth's crust. As a result, hot rock masses from the Earth's mantle are much shallower than in other regions of continental Europe. The geothermal gradient in Hungary is on average 45°C/km, which means that the temperature of the Earth's interior increases by 45°C for every 1 km of depth. In Poland it is 33°C at 1 km of depth. Lake Heviz has an area of 4.4 ha. Depending on the season, the water temperature varies from approx. 24°C in winter to 36°C in summer. The water source is located at a depth of 38 m and is so efficient – a flow of 410 l/s that the water in the lake is completely replaced within 72 hours. In addition, water is rich in sulphur compounds and dissolved minerals and dissolved gases that settle on the skin and then penetrate the body. "Baths in thermal water support the treatment of diseases of the musculoskeletal system, diseases of the thyroid gland and gastrointestinal tract" [11].

While staying in Europe, it is worth paying attention to the thermal springs located in Italy. The thermal waters located in Volcano, located in the Aeolian Islands archipelago, are especially popular. The volcanic origin of the islands results in one of the types of thermal waters in this area being lakes fed with sulfuric water, which has pro-health properties.

Thermal water pools are also located in the Middle East. One of the most famous springs of thermal waters is located in the Hammamat Ma'in desert area. The thermal water present in the desert is a real sensation. In addition to high temperature, the spring is characterized by a high level of salinity and concentration of minerals. There are also a number of thermal springs and pools in Asia, but the most famous are those located in Japan, in particular in Nagano Prefecture. Interestingly, thermal springs are also found in North America. Apart from the thermal waters located in the USA, the most famous pools of this type are those located in Hierve el Agua, Mexico.

There are also rich resources of thermal waters on the antipodes. Examples of these types of springs are those located beneath New Zealand's Hot Water Beach, where, at low tide, the thermal water level rises so much that the thermal waters fill the cavities in the sand. Poland also has rich deposits of thermal waters. It should be emphasized that thermal waters occurring in Poland are characterized not only by high temperature, but also by a rich mineral composition, which makes them willingly used in healing treatments. The warmest thermal springs are located in the Dolnośląskie Voivodeship in Lądek – Zdrój, where the water temperature in thermal pools ranges from 25-44°C. However, thermal water springs are found throughout Poland, also in the Mazowieckie Voivodeship – including Konstancin – Jeziorna near Warsaw. Thermal waters occurring in Poland are sodium-chloride, iodine, sulphide, calcium bicarbonate, sodium bicarbonate, sulfide-fluoride, radon-sulfide. Their use includes the treatment of dermatological ailments, digestive system diseases, kidney diseases, diabetes, rheumatic diseases and peripheral vascular diseases. As emphasized by the analyzed medical publications, the quality and effectiveness of thermal waters present in Poland are not inferior to similar sources located in Europe or Asia.

Summarizing the discussed issue, it can be stated that thermal waters with different mineral composition, temperature and shape occur all over the world. In each of their places of occurrence, they are not only a tourist attraction, but are also used as a source of ecological energy and a natural remedy for various ailments.

Use in technological processes - food and cosmetics industry

Thermal water is a natural source of many minerals extracted from underground springs. The rich mineral composition makes it more and more commonly used as an ingredient not only in cosmetics, but also in products intended for consumption. Some of the oldest thermal waters are extracted from a depth of several thousand meters, which means that they are still filtered at this stage, thanks to which they are saturated with minerals present in the rocks for

millions of years. When they come to the surface, they are already a rich source of minerals and chemical compounds, and thanks to appropriate treatment, they are used to improve the physical condition of cosmetic products and, more and more often, food products [12]. Thermal waters are a source of valuable nutrients that can counteract the negative impact of the environment in which the vast majority of humanity lives on a daily basis.

Characteristics and application of thermal waters

Thermal waters are a special type of groundwater because the temperature of their extraction – right at the intake – is higher than the ambient temperature. Additionally, thermal waters are always characterized by a temperature above 20°C. The vast majority of thermal waters extracted in the world are characterized by a high degree of transparency, and in addition, their chemical composition is a unique representation of the geographic nature of the area where they are extracted. As a result, the chemical composition of each type of thermal water, and thus their health properties, are not only varied, but even unique, because their individual types are present only in specific areas of the globe [13]. Regardless of the place of extraction, however, thermal waters have one universal feature, namely they are microbiologically clean.

Table 1. The influence of ions occurring in thermal waters on the human body

Ions/compounds	Function
Sodium and chloride	Responsible for regulating the electrolyte balance; Help to maintain the proper level of skin hydration; Sodium is responsible for the transport of other minerals – the sodium pump phenomenon – and additionally increases the immunity and improves blood circulation in the skin - it is possible as sodium is deposited in the stratum corneum of the skin, creating the so-called salt coat, which facilitates the osmotic absorption of other elements.
Magnesium	Magnesium is involved in the process of combating oxidative stress, and is also an important component of many processes of producing and supplying energy to the body.
Zinc	It takes part in antioxidant processes and increases the activity of the immune system; It is used in the process of tissue healing and in the process of fighting inflammation – readily used in dermatology thanks to its anti-inflammatory effect; A key element in the process of nail and hair growth.
Copper and Iron	They support the process of breaking down free radicals, provide energy.
Silicon compounds	They participate in intercellular communication; They influence the regulation of metabolic processes; They make collagen fibers in the skin more elastic and accelerate wound healing.
Sulfur compounds	The proteins of hair and nails are made of sulfuric amino acids.

Due to the varied chemical composition, thermal waters are widely used in medicine, including cosmetology (Table 1). Depending on the type of rocks through which the water is filtered, thermal waters of volcanic origin can be distinguished, as well as the only Uriage thermal isotonic water in Europe, derived from the Alps. Classification of thermal waters due to the dominant content of individual elements and minerals [14].

The characteristic properties of thermal waters relate to the soothing properties and anti-inflammatory properties that characterize the vast majority of thermal waters extracted in the world. The healing properties result from the fact that the minerals it contains are deposited in the horny layers of the epidermis, and the minerals present in higher concentrations also penetrate into the deep skin and initiate healing processes. Thermal waters are exploited to the greatest extent in France, Germany, the USA, New Zealand, as well as in Japan and Iceland.

One of the most famous thermal waters used in the cosmetics industry is the Vichy thermal water. This type of thermal water is unique on a global scale, the chemical composition, which is due to the fact that it is volcanic water, which is extracted in the region of extinct volcanoes in central France. It is water that was formed by volcanic activity 380 million years ago. Nowadays, the mined seams are the result of rainfall that took place about 1000 years ago, during which water penetrated deep into the volcanic rocks and in the filtration process it got to the magma chambers, which caused that it was saturated with carbon dioxide, and during the extraction it was additionally in the volcanic rocks. minerals trapped in volcanic rocks appeared in the composition [16]. The rich mineral composition of water makes it used in cosmetics by Vichy. The name is a clear reference to the area where the water is extracted. The composition is unique because it is a combination of as many as 15 minerals and trace elements, i.e. [17]:

- calcium – has anti-inflammatory properties;
- iron – supports skin regeneration and its oxygenation;
- lithium – has anti-inflammatory properties;
- manganese – is an antioxidant;
- potassium – is responsible for strengthening the lipid layer of the skin and improves its hydration;
- magnesium – stimulates skin repair processes;
- boron – has a healing effect, increases the regenerative processes of cells;
- silicon – strengthens capillaries, stimulates regeneration;
- strontium – has anti-inflammatory properties, reduces itching, minimizes irritation;
- sulphur – is a strong antibacterial component;
- bicarbonates – have a cleansing effect and at the same time strengthen the protective layer of the skin;
- fluoride – is another powerful antioxidant;

- sodium – is responsible for regulating skin hydration processes;
- orthophosphates – stimulate cellular processes;
- ammonia – essential in the synthesis of amino acids, it rebuilds the skin.

The concentration of minerals in Vichy water is one of the highest among all waters used in cosmetics. It amounts to as much as 5.2 g/L, and in addition, this water has the largest amount of trace elements, i.e. lithium, silicon or iron, which is one of the main premises determining the use in cosmetic preparations.

The action of water is best seen in four areas [18]:

1. restoration of skin integrity – its use stimulates skin cell renewal and additionally, the processes of keratinocyte differentiation. It also strengthens the lipid barrier and increases the content of calcium and magnesium in the epidermis, which helps to retain moisture in the skin;
2. stimulates regenerative and repair processes – it is possible by accelerating the processes of rebuilding the hydrolipid layer. It also reduces epidermal discoloration;
3. strengthens natural antioxidant mechanisms – stimulates the synthesis of enzymes – superoxide dismutase, catalase and glutathione peroxidase – which are involved in the process of neutralizing the influence of free radicals. Additionally, it modulates the expression of genes that are responsible for antioxidant processes and reduces the influence of oxidative stress caused by the influence of UV rays;
4. soothing properties – reduces the level of skin sensitivity by reducing inflammatory processes.

Another famous thermal water is Europe's only isotonic thermal water from Uriege, France. It is the most highly mineralized thermal water used in the cosmetics industry. Its composition is based on a high content of mineral salts of 11 g/l, which means that it does not change the size of skin cells, and therefore does not affect its integrity. What's more, its unique mineralogical composition – close to the natural moisturizing factor of the skin, causes Uriage Water to restore its natural chemical balance, and additionally strengthens its protective barrier and reduces epidermal water loss. Thanks to the content of copper, it also has an antioxidant and anti-inflammatory effect on the skin. Additionally, it improves the thickness of the granular and horny layers of the epidermis.

The content of minerals and trace elements causes that thermal waters are widely used as one of the main ingredients in cosmetics intended for skin care with dermatological problems. Thermal water is used as an effective remedy in the case of Atopic Dermatitis – (AD) – because the zinc contained in it has antibacterial and anti-inflammatory properties, which means that it soothes irritations caused by the disease. In addition, thermal water is also the base of cosmetics dedicated to people who have suffered sunburn. The rich mineral composition not only soothes irritations, but also accelerates the regeneration rate of the lipid layer and has a tonic character. Interesting is [19] – the use of thermal water in cosmetics intended for men, and more precisely in shaving cosmetics.

The use not only soothes the irritation caused during shaving, but also softens the stubble itself, which affects the quality of the shaving. Thermal water is one of the main elements of cosmetics prepared for the youngest users, babies who may suffer from the so-called diaper rash skin irritation. This market segment also uses its toning properties and strengthens the skin's protective mechanisms. However, as the producers themselves recommend, in the case of cosmetics containing thermal water dedicated to babies, it is recommended to consult a doctor beforehand, as some children may have an allergic reaction to the ingredients of the preparations, which, although used in accordance with the applicable standards, may harm them. In addition to being used in the cosmetics industry, thermal waters are increasingly used in the production of food products. The use of thermal waters for food purposes has been known since antiquity. Already in Ancient Greece, drinking thermal water was supposed to soothe the nerves of Greek women. In Rome, a visit to the thermal baths was considered one of the obligatory "duties" of every respected citizen, because it was there that the real social life of the city took place. Also in Poland, already in the 18th and 19th centuries, publications were available that drew attention to the beneficial effects of consuming thermal waters, which were considered an effective remedy for migraines and the "shattered" nerves of the ladies of that time.

Nowadays, it is recommended to consume thermal water due to the influence it has on the pace and course of metabolic processes. Moreover, the regular use of a drinking treatment consisting of various types of mineral water is an effective way to supplement the deficiencies of micro and macro elements that may occur in the human body. In addition, the chemical composition and the content of trace elements improve the overall condition of the body, and alleviate the psychological effects of the negative impact of the environment, improving the "well-being" of people consuming thermal waters. Another of the advantages of using a drinking cure consisting of thermal waters concerns the human immune system. Regular consumption of even small amounts of thermal waters strengthens the immune system, which in turn reduces the number of diseases and their course [20]. The original food use of thermal waters was related to the fact that they help remove toxins from the body. Consuming thermal waters, although it has many health benefits, should be consulted with a doctor beforehand. This is due to the fact that not all types of thermal waters are suitable for direct and unlimited consumption. The chemical composition and general mineralization, including high carbon dioxide saturation as well as sodium and fluorine, mean that they should be consumed only in certain amounts determined by the doctor, because the excessive supply of minerals and trace elements to the body may adversely affect the functioning of the most important organs, disrupting their work and weakening the entire body. Therefore, in the vast majority of cases, their consumption is recommended in a formal form during stays in spas. The available types of water are used in the treatment of obesity and diabetes. The use of thermal waters fights pancreatitis and gall bladder

inflammation, which improves the quality of life of patients. In addition to direct consumption of thermal waters, research has been conducted in the last decade on the use of thermal waters for the production of certain food products. Currently, work is underway on the breeding of various species of algae that can be used both as an ingredient of animal feed and by humans. The culture based on thermal water causes the natural accumulation of minerals and trace elements in the algae, which then become a natural ingredient of the prepared foods. This makes it possible to limit the artificial "reinforcement" of, for example, feed for farm animals, which not only affects the taste of the meat itself, but also causes that it contains less artificial nutrients, which means that it is healthier for the consumer [21]. Such practices are commonly used, for example, in Japan, where algae grown with the use of thermal waters are a key nutrient in the production of one of the world's most expensive types of beef, namely Kobe beef.

Thermal waters are also used in our latitudes. Iceland is the best example of their universal application. Until recently, geothermal sources were used there only for heating houses as well as a kind of tourist attraction. Thermal water was used for bathing and drinking, and as a source of ecological energy to heat Icelanders' homes. However, it has also been used for heating and irrigating greenhouse crops for almost two decades. Thanks to this, it is possible to breed vegetables and fruit, which so far had to be imported from other countries. Moreover, the development of effective methods of thermal water treatment has resulted in the fact that they constitute a valuable resource for the state's "agricultural" sector. Vegetables and fruit grown with the use of thermal water are characterized not only by an increased mineral composition, but thanks to the properties of the water itself, they are more resistant to adverse conditions in Iceland. The application significantly reduces the need to use artificial fertilizers, which makes the crops almost fully ecological, and thus more friendly to both consumers and the natural environment.

Summary and conclusions

Thermal waters have been used in widely understood cosmetology since ancient times. The cosmetics industry is increasingly turning to the natural and ecological ingredients, which significantly determines the increased interest in the use of thermal waters as an ingredient in cosmetics dedicated to both men, women and children, observed in the last quarter of a century.

Owing to the unique chemical composition, rich in minerals and trace elements, thermal waters soothe both the outer layer of the epidermis and, by penetrating into the cells, also on the deeper layers of the skin. They soothe irritations caused by diseases and sunburn. Cosmetics containing thermal waters are characterized by anti-inflammatory and antioxidant properties, improving not only the appearance of the skin, but also the level of its hydration. What's more, they help to strengthen the skin's protective mechanisms. However, the analysis of the available publications allowed to present also another application of thermal waters, which are also used in the food industry.

Thermal waters are used for irrigation of crops as well as for obtaining natural nutrients added to the feed of farm animals. The use of thermal water subjected to appropriate filtration processes has a positive effect on the quality and health properties of the cultivated consumer products and eliminates the need to use artificial fertilizers and strengthening agents, which makes these crops almost completely ecological, and thus have a significantly lower negative impact on the natural environment.

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