Journal of Ecological Engineering
Volume 18, Issue 6, Nov. 2017, pages 185–191
DOI: 10.12911/22998993/75692

Review Article

THE USE OF GEOTHERMAL WATERS IN PODHALE IN TERMS OF TOURISM AND INDUSTRIAL APPLICATIONS

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Received: 2017.09.15
Accepted: 2017.10.01
Published: 2017.11.01

ABSTRACT

Recently, an increased interest of various industrial and economy branches in geothermal waters has been observed. In Poland, one of the most famous geothermal systems is the Podhale Basin, which forms an important reservoir of geothermal waters with relatively low mineralization and high temperatures. More and more often geothermal water is used not only for balneological or recreational purposes, but also as a heat source for heating. New areas of application of geothermal waters are also appearing, e.g. the use of cooled geothermal water as a raw material to produce fresh water. Another example of the application of geothermal waters is the cosmetic industry. For instance, a cream based on geothermal water from Podhale was introduced to the cosmetics market in 2013. This paper presents the possibilities of using the geothermal waters of Podhale, with particular emphasis on geothermal waters from Banska PGP-1, Banska IG-1 and Banska PGP-3 boreholes.

Keywords: geothermal waters, Podhale area, waters mineralization, water destination, heating, balneotherapy

INTRODUCTION

The heat causing the emergence of geothermal waters comes from the center of the Earth. Its main source is liquid magma, and additional – natural processes of decay of radioactive elements [Bogdał and Kowalik 2015]. Geothermal waters, also called thermal, are mainly mineral waters (TDS >1 $g \cdot dm^{-3}$) or less usual – regular waters, whose temperature measured at the outlet from natural sources or wells is at least 20 °C. This volume is a conventional boundary used in balneology for many years [Dz. U. No 133, item 883].

Hydrodynamic and hydrogeochemical conditions of the Podhale Basin waters were the subject of studies by Kępińska [2006; 2009]. The author examined, among the other things, the issues related to the evolution of the Podhale system thermal conditions, secondary mineralization and thermodynamic state of geothermal water – reservoir rocks. In her works she also pointed to the desirability of introducing a monitoring system, as one of the elements of a rational management of the Podhale geothermal waters.

Isotopic analysis ($\delta^{18}O$, δD, tritium activity) of the geothermal water basin, were conducted by Małecka and Nowicki [2002], who confirmed meteoric origin of these waters and identified their age as the Holocene. Studies of concentrations of noble gases in the Podhale Basin geothermal waters were conducted by Chowaniec and others [2009]. According to them, geothermal waters in the northern part of the Podhale Basin, are in the zone of very slow flows and are much older than the waters of the Holocene age located closer to the outcrop. These results indicate that zones of the low resource sustainability exist in the Podhale Basin area.

The problem of disposal and / or management of post-exploitation of geothermal waters was

raised by Tomaszewska in her studies [2009]. She presented the concept of geothermal water desalination in order to obtain drinking water. Desalination process was carried out in a pilot geothermal water desalination plant in Bańska Niżna, using the method of ultrafiltration and reverse osmosis [Tomaszewska and Pająk 2012]. A post-production concentrate is a by-product of the desalination process. The possibilities of management of the concentrate were analyzed, inter alia, by Kotowski and Satora [2011].

PURPOSE AND SCOPE OF WORK

The aim of the study is to present and discuss the use of geothermal waters found in the Podhale Basin in terms of their use for recreational as well as for industrial purposes. In addition, the study analyzes the effects of energy optimization and economic investments related to the use of geothermal waters.

The scope of work includes the characteristics of the geological structure of the Podhale Basin based on existing literature reports and the characteristics of the areas of current geothermal waters use have been given. Potential concepts of using of geothermal waters have been indicated in the summary.

OUTLINE OF THE GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS

Some of the most favorable conditions for the operation of thermal waters in Poland are located within the Podhale Basin. They affect the geological and hydrogeological conditions in this area: high outflow temperature (up to 90°C), low mineralization (up to 3 $g \cdot dm^{-3}$), high well discharge (up to 550 $m^3 \cdot h^{-1}$ from a single borehole) and easy accessibility of terrain. [Chowaniec 2003]. The reservoir that forms the Podhale Basin stretches out from the northern edge of the Tatra Mountains to the Pieniny Klippen Belt, which is also the limit of geothermal waters reservoir. The Tatra Mts. are a supply source area of the Podhale Basin. Rainwaters infiltrate into the unsaturated zone, and then flow to the north, where they encounter a complex of hardly-permeable flysch sediments, which split groundwaters into two streams (Figure 1)

The upper stream supplies the hypergene zone in the flysch rocks – these are fresh waters of mineralization below 1 $g \cdot dm^{-3}$. The lower stream flows through a phreatic zone to Paleogene carbonate rocks as well as to Mesozoic deposits of the Tatra formations [Chowaniec 2003]. With an increasingly high residence time, these waters heat up slowly and reach mineralization up to approx. 3 $g \cdot dm^{-3}$. In the Zakopane vicinity, at a depth of approx. 1000 m, the temperature of the geothermal water is approx. 26 ºC, while in Bialy Dunajec and Bańska regions these waters have the temperature of over 80 ºC.

Geothermal collector's geochemical environment (Middle Eocene and Mesozoic) shows the characteristics of the environments which used to be filled with brines and then washed by meteoric waters in the recent past [Watycha 1976]. A remnant of this process is the large amount of sodium ions, absorbed on the rock matrix, currently being released into groundwater by ion exchange. As a result of this process, the groundwater circulating in the less washed zones, has a rNa/rCl value of (1.5÷2.1) and relatively high content of sodium. In chemical terms, the Podhale Basin waters contain a large amount of sulphate (VI), sodium and calcium ions. These are mostly waters of Na-Ca-SO4-Cl-B or similar type. Their chemical composition is shown in the Piper's diagram (Figure 2).

Total dissolved soils (TDS) of these waters is relatively low and usually varies between 2.2 and 2.8 $g \cdot dm^{-3}$. During the operation, a decrease of their TDS was observed. [Kępińska, 2006]. However, the reduction in the TDS is not fixed in time, therefore, the interpretation of this phenomenon requires additional studies and further monitoring of the chemical composition of these waters [Kępińska 2009; Kotowski and Satora 2012].

AREAS OF USE OF THERMAL WATERS

District heating

One of the main uses of thermal waters in the Podhale region, is their use as a heat source for heating. At PEC Geotermia Podhalańska SA, geothermal heat is obtained from the thermal waters exploited through Bańska PGP – 1, Bańska IG – 1 and PGP – 3 boreholes [Wartak et al. 2007]. Biały Dunajec PGP – 2 oraz Biały Dunajec PAN – 1 are injection boreholes intended for void waters injection. The existing heat distributing network systematically expands its

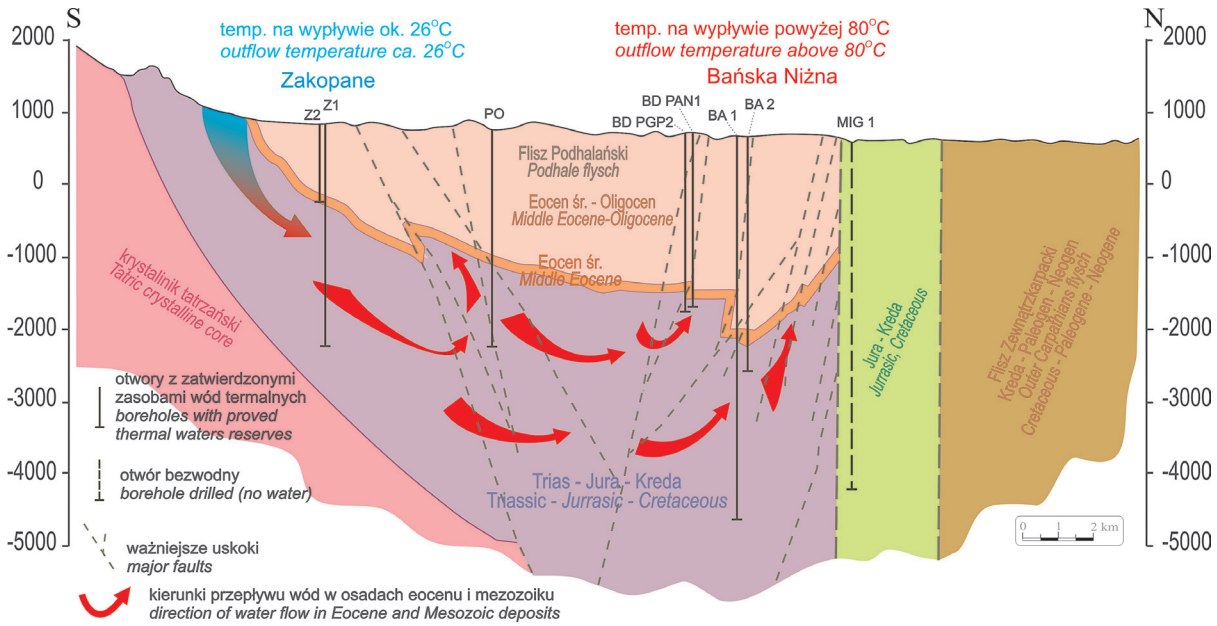

Fig. 1. Geological cross-section (acc.to Chowaniec et al. [2009] amended and supplemented by the authors)

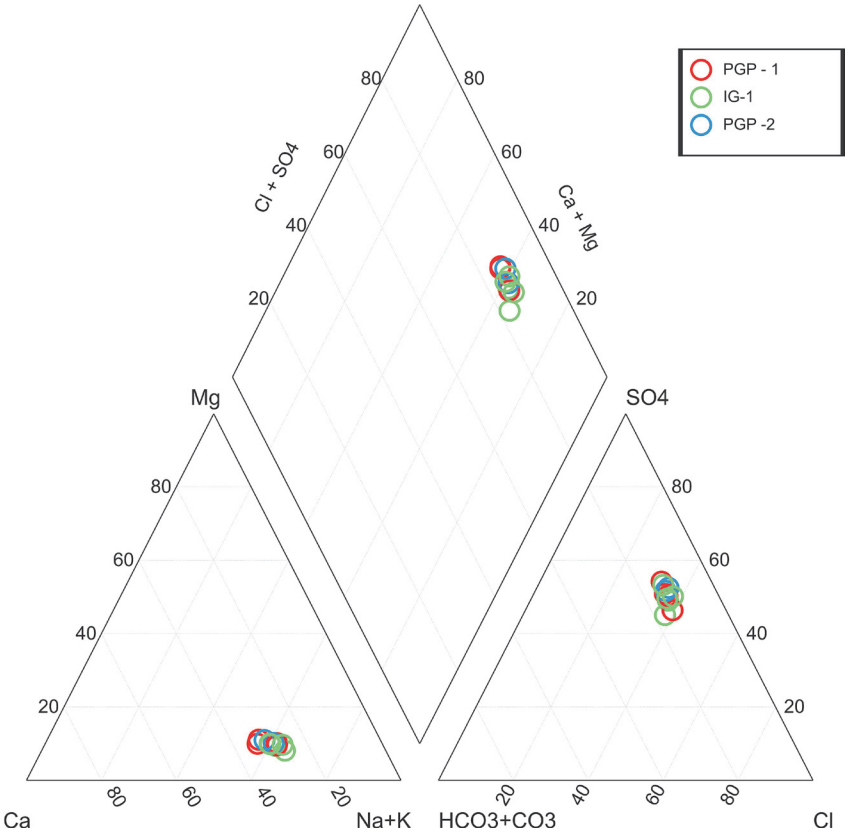

Fig. 2. Chemical composition of thermal waters from IG-1, PGP-1 i PGP-2 boreholes

recipients. It is possible not only due to its continuous expansion but also due to the good properties of the geothermal collector, i.e. high temperature of water, relatively low mineralization and adequate discharge of the output wells. The PEC Geotermia Podhalańska SA company, being a manufacturer and distributor of the thermal energy in both Nowotarski and Tatrzanski counties, has wired up so far more than 1000 facilities, both individual and large-scale. Connecting more recipients to the district heating network causes elimination of local sources of air pol-

lutant emissions. In the area of Podhale, where heating season sometimes lasts for half a year, this is of great importance.

The concept of transformation of geothermal waters in freshwaters

Given the shortage of fresh groundwaters in the area of the existing geothermal plant in Bańska Niżna, the concept of management of the post-exploitation, cooled geothermal waters, relying on converting them into drinkable water has been proposed [Tomaszewska 2009].

According to this concept, a 2-hybrid desalination system, combining an ultrafiltration with a double reverse osmosis, is most suitable. The economic analysis of geothermal water desalination process conducted by Tomaszewska and Pająk [2012], has led to a conclusion that it is not possible to determine the profitability of implementation of the process of obtaining drinking water of geothermal waters. In the case of Bańska Niżna, for simple economic model which assumes the sale of drinking water, the authors of the study have identified the projected return of investments for approx. 14 years. This model assumed, among others, desalination of the geothermal waters on an industrial scale (well's discharge of 120 m^3/h and recovery rate of 50%). However, Kotowski and Satora [2012] pointed out that the operation of the desalination plant on this scale can have a negative impact on the quality and quantity of geothermal water resources.

The concept of obtaining drinking water also assumes the use of a concentrate, which is formed as a by-product in the process of water desalination. According to Tomaszewska and Pająk [2012], the assessment of the possibilities for implementation of the desalination process on an industrial scale depends precisely on the directions and possibilities of utilization and/or management of the concentrate. The use of the concentrate for balneologic and recreational purposes may be conditioned by the necessity of its reprocessing (among others, in order to eliminate high boron concentrations), which calls into question the economic profitability of the process [Kotowski and Satora, 2011]. Other ways of using the concentrate on an industrial scale, for example as a source of boron and/or strontium, have been considered as undevelopmental.

At present, in accordance with the suitable water-rights permission, post-exploitation geothermal waters are discharged into the Bialy Dunajec river. Such actions are not beneficial in the context of sustainable management of groundwaters and surface waters. This is due to the fact that the geothermal waters, beside high mineralization, often contain high concentrations of trace elements such as boron, barium, strontium, fluorides, bromides, and heavy metals [Tomaszewska and Pająk 2012].

The use of geothermal waters in balneology and recreation

Geothermal waters are also used for balneorecreational purposes. The most of balneorecreational centers in Poland are located in Podhale. They are: Terma Bania, Terma Bukovina, Szymoszkowa and Szaflary Baths. The waters of the Zakopane IG-1 and Zakopane-2 boreholes are used in the first geothermal pool in Poland – Aqua Park Antalowka in Zakopane. This object is also heated by the geothermal energy. In February 2015, a new sports and recreation complex "Hot Stream" in Szaflary, which uses geothermal water coming from the PEC Geotermia Podhalanska SA geothermal wells (Figure 3 and Figure 4). The entire facility, including sanitary and catering departments, is also heated by the geothermal energy. UV lamps are used for water treatment in swimming pools. It is the first and only of its kind object where this method is used in water treatment in Podhale.

Balneological properties of the Podhale geothermal waters are associated with high concentrations of components such as: hydrogen sulfide, sulfides and sulfates, silica, fluoride, strontium and potassium [Ciągło 2007]. The impact of geothermal water on the body, manifests itself through a number of positive changes associated with the cardiovascular system and the endocrine [Ponikowska 1995]. Hydrogen sulfide baths soften the epidermis, they also cause desensitization and vasodilation of the skin. There are many indications for hydrogen sulphide bathing. The most important are: chronic arthritis, neuritis of toxic origin, conditions after heavy metal poisoning, neuralgia, reproductive organ diseases, psoriasis and urticaria [Karski et al. 2000].

Fig. 3. Geotermal heating plant in Bańska Niżna (photo from www.geotermia.pl).

Fig. 4. „Gorący Potok" sports and leisure complex (photo P. Bugajski)

The use of geothermal water in the cosmetics industry

The use of geothermal waters for the production of cosmetics, is another area of development of these waters. Microbiologically pure geothermal water, with proven stability of the chemical composition, can be used not only for bathing, inhalation or wraps, but also as an ingredient in preparations for skin care [Sapińska-Śliwa et al. 2009]. Geothermal waters provide the body with minerals and trace elements that are necessary for the proper functioning of cells and tissues. The qualitative composition of micronutrients in geothermal waters often corresponds to the qualitative composition of the human body fluids [Léauté-Labrèze et al. 2001; Żebrowska and et al. 2003].

Geothermal water can alleviate skin irritations caused by photodynamic treatment [Goldman et al. 2007], or irritation caused by chemical agents used to fight wrinkles and acne [Alizerai et al. 2007]. The market's most well-known products that contains geothermal waters in its composition are products of Vichy, La Roche Posay and Avene. In case of domestic products, there are available cosmetics based on geothermal waters from Iwonicz-Zdrój Busko-Zdrój. Cosmetics using the Podhale Basin geothermal waters are produced by Termissa. In 2013, the company has produced and introduced a nutrient moisturizer, containing the geothermal water from Podhale [http://termissa.eu/], borehole in its (Figure 5). The impact of geothermal water is manifested by a high content of large quantities of minerals in this case.

Fig. 5. „TERMISSA" Nutrient moisturizes (authorial photography)

The Termissa company plans to expand the range of cosmetics by new products containing the geothermal water from the Podhale Basin.

CONCLUSION

Considering the qualities of the Podhale region, an occurrence of one of the most favorable conditions in Poland for using the geothermal waters, should be pointed out. They have been widely used due to the high temperature at the outlet, relatively low mineralization and high performance of these water-intakes. Special attention should be paid to their use as a heat source for heating over 1000 different types of facilities. There is also more widespread recreational and balneological use of the Podhale geothermal waters, making use of their temperature, and high concentrations of hydrogen sulfide, sulfides, sulfates, silica, fluoride, strontium and potassium. In recent years also the cosmetics industry have begun to develop, using the geothermal waters in its products. The possibility of using post-exploitation geothermal waters, involving the processing through the process of desalination into drinking water, has also been considered. However, in this case, it was found that it is impossible to universally determine the economic profitability of implementation of this process, since the operation of geothermal water desalination plants on a large scale, may have a negative effect on the qualitative and quantitative resources of geothermal waters. In addition it is determined by the utilization and development of the concentrate, which is formed as a by-product in the process of desalination.

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Pracę dofinansowano ze środkówWojewódzkiego Funduszu Ochrony Środowiska i Gospodarki Wodnej w Lublinie.