

THERMAL SPRINGS AND SPAS IN POLAND

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SUMMARY

Geothermal waters from springs and wells are currently used in eight spas and water centers in Poland. These resorts have a long and interesting history, being an important part among all the health spas in the country. The demand for geothermal curative and recreation services offered in spas constantly increases. The paper presents several cases of geothermal resorts and some examples of initiated and planned new projects which will often be executed as a part of complex systems of geothermal energy application both for space heating and curative purposes. In several places, there are proposals to construct new geothermal resorts based on warm waters supplied by wells. Balneo-therapy and bathing using natural warm waters constitute potential sector of geothermal activities and business in Poland.

INTRODUCTION

The tradition of use of geothermal waters for bathing and balneo-therapy has old roots in Poland. The first written records report that since the 12th century warm spring waters have been used for balneo-therapy in some localities. Through the centuries, warm springs were used in the Sudetes and Carpathians mountains. Yet, undergoing up- and down-periods, this practice increased over time, to the point that some locations (Cieplice, Duszniki, Iwonicz) became quite renown spas in Central Europe. With time, several other spas using geothermal waters have been founded which are still in operation (Sokolowski, et al., 1999).

With this background, the country is still at the very beginning of geothermal application for space heating and other agricultural and industrial uses, as such activities only date back to the 1980s. In 2001, three geothermal space-heating plants were online: in the Podhale region, in Pырzyce town and in Mszczonow town (Kepinska, et al., 2000). Several other feasibility studies and utilization projects are in progress. Most of the project, already under construction and planned, provide the use of the geothermal waters for the recreation and therapeutics besides their heat application.

In the recent years, the growth of interest in recreation and water centers development, as well as water therapeutics including the geothermal water application have appeared in Poland. It concerns the operational spas as well as – it's worth to notice – the localities, which have never dealt in this field as they plan to develop that activity from the very beginning using the geothermal water discharged by

existing or planned wells. This sector of recreation and therapeutics has great prospects for development and economic attraction.

The demand for the geothermal treatment services is great and still growing. The spas carry out the modernization of the facilities and upgrade their service despite the financial and legal difficulties resulting from the change of the ownership and financing rules of the spa enterprises. The fees for lodging and service are being revised as well. Many spas prosper by achieving the proper European standards.

GEOTHERMAL RESOURCES

Poland possesses large low-enthalpy geothermal resources to be found within about 80% of its territory (Sokolowski, 1995). They are connected with extensive geothermal provinces predominantly built of sedimentary basins with numerous geothermal aquifers (Figure 1) which are as follows:

- The Polish Lowland Province. It forms the most extensive and promising unit containing numerous geothermal aquifers (Palaeozoic-Cretaceous). The reservoir temperatures range from 30 to 130°C (1-3 km of depth). The TDS range from 1 to 300 g/L.
- *The Fore-Carpathian Province.* Geothermal aquifers occur in Mesozoic-Tertiary rocks. The reservoir temperatures range from 25 to 50°C; while, the TDS varies from several to about 100 g/L.
- *The Carpathian Province.* Geothermal aquifers are connected with Mesozoic-Tertiary formations. The TDS range from 0.1 to about 100 g/L.
- *The Sudetes Region.* It is characterized by a limited possibility of geothermal aquifers occurring in fractured Precambrian and Palaeozoic crystalline rocks.

Considering the present prices of traditional fuels, feasible geothermal plants can be built in about 40% of Poland (Kepinska, et al., 2000). The most favorable reservoir conditions exist in the Polish Lowland (Sokolowski, 1993 and 1995; Gorecki, 1995 and 1998; Ney, 1995) and in the Podhale region (Kepinska, 2000).

GEOTHERMAL BALNEO-THERAPY AND BATHING

General

In Poland, there are 36 spas using underground waters for balneology and bathing. Among them, eight spas use 20 - 62°C geothermal waters (Figure 1) issued by natural springs or discharged by wells. Usually, both cold and warm waters are provided. The main information on localities using geothermal waters for bathing and curing is given in Table 1.

Polish spas (including the geothermal ones) act according to the legal regulation concerning spas and balneology, which was adopted in 1966 and updated in 1990. At present (2001), a new law is expected to be passed. The spa localities hope for prosperous and sustainable economic development resulting from recreation and balneology. This hope is expressed by the establishment of many so called spa boroughs within the entire country. There is a boom in the production of mineral water in many spas and their sale in both the country market and abroad. The development of balneology and spa services in Poland requires supporting state and self-government policy. Among others, the Economic Chamber – Polish Spas was created for this purpose. It is an organization of companies and institutions dealing in spas. Its main task consists of representing spas' interests against home and foreign bodies, acting for the development of the existing spas, and establishing new ones, participation in legislative works, promotion, and the elaboration of the spa standards. The necessity of the adjusting spa service to European standards is being realized. The role of the local self-government in spa management, as well as the other activities serving the sustainable development of such localities should be emphasized.

Geothermal Spas – Selected Cases

The oldest spas in Poland are located in the Sudetes Mountains. (SW-Poland). During the centuries, that region has been famous throughout Central Europe for its landscape and numerous health spas. Abundant mineral springs have been used there for healing purposes. Some of them issue geothermal water that contributed to the flourishing of certain resorts like Cieplíce Spa, Ladek Spa and Duszniki Spa. In the Polish Lowland in two localities, Ciechocinek and Konstancin, cold and geothermal waters produced by the wells are used for treatment and recreation. Three resorts using geothermal waters for specific application are situated in the Carpathian Mountains (S-Poland): Iwonicz Spa, Ustron and Zakopane. This region abounds with low-temperature mineral springs, which gave rise to numerous health resorts. The most famous among them are Krynica and Szczawnica. On the contrary, warm springs are very rare there, and were known in Iwonicz and Zakopane only (Figure 1); while at present, geothermal balneo-therapeutical and water centers are based on water supplied by wells.

To give insight into geothermal spas and water centers in Poland, some selected cases are presented in the following.

Cieplíce Spa

Having the warmest curative waters in Poland, Cieplíce (Figure 1) is one of the most famous and visited spas in Poland. Its convenient location close to the frontier attracts patient and tourists from the neighbouring countries – Czech Republic and Germany. Natural outflows of warm waters were already known there in the 13th century when they started

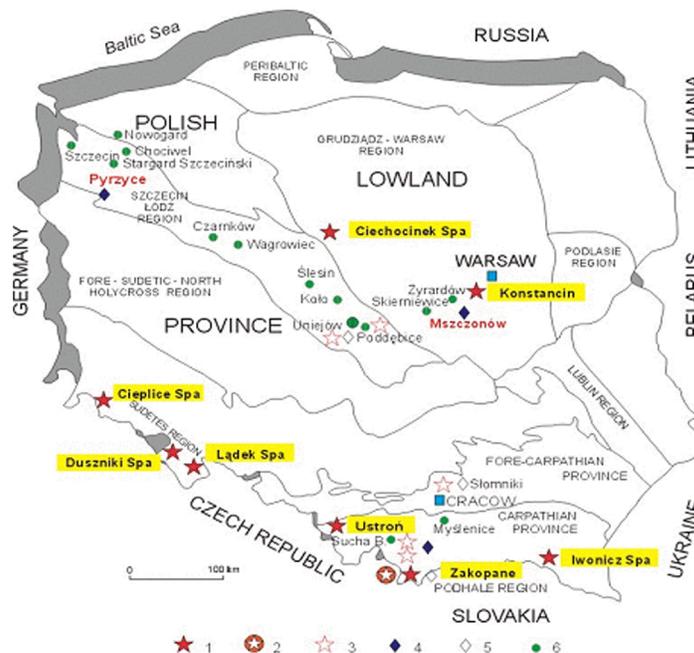


Figure 1. Geothermal spas in Poland (geothermal division based on Sokolowski, 1995).

Geothermal spas and water centers: 1. on-line, 2. under construction, 3 – planned to construct.
Geothermal space heating plants: 4. on-line, 5. under construction, 6. planned to construct

Table 1. Polish spas using geothermal water for bathing and balneo-therapy (based on Kepinska, et al., 2000)

Locality	Type of water intake	Maximum utilization			Annual utilization	
		Flowrate kg/s	Temperature, °C		Average flowrate kg/s	Energy use ^{b)} TJ/yr
			Inlet	Outlet		
Zakopane	w	36	26-36	25	18	14
Cieplice Spa	s + w	7.5	36-39 ^{a)}	26	6.0	10
Ladek Spa	s + w	11	20-28 s 44w	20	10.8	16.8
Duszniki Spa	s + w	5.5	19-21	19-21	5.5	0.3
Ciechocinek Spa	s + w	56.8	27-29	20	4.2	2.8
Konstancin	w	2.5	29	12	0.1	0.2
Ustron	w	0.9	28	11	0.4	0.58
Iwonicz Spa	s + w	3	21	10	0.4	0.58

w – well, s – spring, ^{a)} mixture of 20-62°C waters from springs and wells (20-62°C),

^{b)} energy use (TJ/yr) = Annual average water flowrate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.1319

to be used for treatment (Sokolowski, et al., 1999). This renown European spa was already operating in the 17-19th centuries.

Geothermal aquifers occur within fractured Carboniferous granites of the Karkonosze Mountains massif.

Currently, water flows out from several natural springs and one well. The springs yield about 10 m³/h of water with temperatures ranging from about 20 to 44°C. The well (750 m of depth) is capable of discharging 40 m³/h of water with wellhead temperature of 60-68°C (Dowgiallo, 1976; Dowgiallo & Fistek, 1998). The total dissolved solids (TDS) are about 600 – 700 mg/L (exceptionally up to 1000 g/L), the predominant contributor being SO₄ – HCO₃ – Na – F – Si. The content of H₂SiO₃ amounts to 100 mg/L and is the highest among all geothermal waters in Poland, and is also very high in fluorine (F ion) content – up to 12 mg/L (Dowgiallo, 1976).

Waters are predominantly suitable for therapeutic baths; and they are also used for other treatments, such as orthopaedic-traumatic and neurological diseases, nephropathy and the diseases of the urinary track. The spa offers a wide range of the curative treatment and physical recovery. Mineral waters are also bottled.

The oldest historical record of Cieplice comes from 1281. It was found in a document concerning the donation of "Caldius Fons" (warm springs) to the Silesian monastery of the Knights of St. John of Jerusalem from Strzegom by prince Bernard from Lwowek. In 1288, the first curative house was built and consent was given to erect an inn for the growing number of patients. The Slavonic name *Cieplowod y- "Chleplevode"* (warm waters) can be found in records of the papal functionary Gabriele da Rimini who visited the Silesian villages to collect the overdue taxes.

In the past centuries, the most magnificent patient who visited Cieplice was the Polish queen Maria d'Arquien Sobieska, who came there in 1687. The queen was accompanied by her numerous court, some 1500 people. She was the beloved wife of one of the greatest Polish kings Jan III

Sobieski whose army stopped the Turkish invasion in Europe in the famous battle of Vienna in 1683. Two of the warm springs in Cieplice were named after king Sobieski and his wife.

In the end of the 1990s, the other existing well in Cieplice was deepened from 661 m to 2002 m. The artesian flow of about 90 m³/h water with wellhead temperature of 87.9°C; while, the measured bottom temperature (depth of 1870 m) was 97.7°C (Dowgiallo, 2000). Those works were carried out in response to the growing demand for curative water, planning the sport and recreation facilities, and the project of utilizing the water for heating. Currently (2001), the well is being tested. The start of the utilization projects depends on obtaining the proper funds.

Ladek Spa

The first records of warm waters in Ladek come from 1242. The first bathing house was built towards the end of the 15th century; since then, it developed slowly but flourished in the 19th century. Among numerous visitors who stayed at Ladek for curing, was John Quincy Adams, the sixth President of the United States. He declared at the end of his visit in Ladek: "I have never seen a spa, the location and appearance of which would be as much favourable to health preservation and restoring as Ladek."

Geothermal waters occur in the fractured Pre-Cambrian gneisses. The flowrate from several springs amounts 1 - 17 m³/h, with the temperature ranges from 20 and 30°C. There are also two wells (up to 700 m deep) discharging water with wellhead temperature around 46°C. The TDS is low: 160 – 280 mg/L, but with a high content of fluorine ion (F) (up to 11 mg/L) and H₂SiO₃ (up to 70 mg/L). Radioactive waters harnessed at Ladek Spa are suitable mainly for treating patients with the motor system, vascular, oral and dermatological diseases.

Among Polish resorts, Ladek Spa possesses one of the greatest therapeutic attractions. Wide promotion and advertising of the spa was also addressed to the foreign

clients, particularly from Czech Republic and Germany. Cultural performances are organised and sponsored, a system of preferences and rebates was introduced, and some interesting offers for investors were prepared. Ladek is a good example of proper joint utilization of the geothermal water in curing, recreation, and tourism. It is a town, which offers not only curative services, but also a variety of rest, health preventive treatment and physical recovery (Figures 3 and 4).

Duszniki Spa

Duszniki Spa is located about 40 km west from Ladek Spa. The first records of warm springs from Duszniki come from the year 1408.

Geothermal aquifers are connected with the Pre-Cambrian shists formation. Currently, geothermal waters are produced under artesian conditions from several shallow (up to 160 m) wells. The wellhead temperatures are 17 - 18°C. These relatively low temperatures result from the fact that waters are cooled down on the way to the surface due to expansion of the dissolved CO₂. There also exists one spring named *Pieniawa Chopina* (Figure 5). Geothermal waters from Duszniki represent the type HCO₃ - Ca - Na - Mg. They are rich in iron, CO₂ (up to 2 g/L) and H₂SiO₃ (50 - 90 mg/L). The TDS amounts about 2 g/L (Dowgiallo, 1976).

Duszniki Spa is famous thanks to Frederik Chopin - the great Polish composer and pianist (1810 - 1849), who stayed there for a healing treatment in 1826. He was only sixteen when he came to the resort along with his mother and sister. During his stay in Duszniki the young artist gave one of his first public concerts raising the sincere admiration of the audience. This was one of his first performances, which opened the gateway to the world's artistic career for Chopin (Sokolowski, et al., 1999).

In the 19th century, Duszniki, then belonging to Bohemia, was visited by numerous Poles who had founded a monument to Chopin and a theatre bearing his name. To commemorate the artist genius and his stay in Duszniki, the warm spring was given the name "*Pieniawa Chopina*." It is also worth noting that each year the Chopin international music festival is organised in Dusznik - the oldest one in Poland, gathering outstanding musicians and a large international audience.

In Duszniki, there are some medicine research units, which are managed by country universities of medicine. They deal with balneo-therapeutics. The spa makes its development widely known, namely through the expansion and modernization of recreation and tourism infrastructure, sustainable development, Chopin Festival of Music, promotion and advertising, cooperation with other spas in this region, joint promotion of the curing advantages, and offers for investors.

Ciechocinek

Ciechocinek is situated in Central Poland, on the left bank of the Vistula River Valley (Figure 1). As a health resort, it started to develop at the beginning of 19th century on the base of curative brines with the temperatures of 10-13°C flowing from natural springs.

Geothermal aquifers are found in the Jurassic sandstones. Currently the spa is supplied with cold and geothermal water discharging from several wells. Warm waters are tapped by two wells (depths of about 1300 m and 1380 m) which produce 29 - 37°C waters. The TDS is variable: 3 - 72 g/L, depending on the depth of the aquifer. Waters predominantly represent Cl - Na - F - Br - I - B - SO₄ and H₂S type (Krawiec, 1999).

The content of iodine and bromine comes from the Zechstein salt formations. The salt minerals are dissolved by waters of probably paleo-infiltration meteoric origin.

For curative treatment, both warm iodine-bromine brines and cold waters, are used, and peat is used for highly active peat baths. Patients with gynaecological diseases, rheumatism as well as those having problems with circulation, central nervous system and upper airways can be treated in this resort. The cures consists in hospital, sanatorium, or part-time treatment. Along with water used for treatment and bathing, the production of table salt (with iodine content), several kinds of mineral water, lye and crystalline slime have been carried out.

The development of the town and its neighbourhood commenced after the first partition in 1772 when central Poland lost the access to the Wieliczka salt mine. At that time, brine sources for salt extraction were obtained from there (Sokolowski, et al., 1999).

In 1836, the saline springs started to also be used for healing purposes. In the mid-19th century, a specialized therapeutic station was established in the spring area. In 1841-1860, the first shallow wells were drilled. They discharged brines with the temperatures in the range of 18°C.

According to the project of S. Staszic - the pioneer of Polish geology and mining - specific wooden cooling towers (2.5 km long were built, used for spraying iodide-bromide brines. In this way, an ocean-like microclimate was created, especially suitable for natural curative inhalations. These installations are still in use (Figure 6).

After Ciechocinek was granted city rights (1919), the therapeutic station was a starting point for the rapid development of the city. Then already about 25,000 person per year were treated at Ciechocinek.

At present, Ciechocinek is one of the main Polish resorts. A number of treated persons exceeds 30,000 per year. After financial problems in the beginning of 1990 were solved, Ciechocinek again came into a development period. The following items make Ciechocinek a successful and renown spa:

- Variety and high quality of treatment service,
- Providing treatment means over a wide range,
- Spa facilities strictly satisfying the requirements of curing people.
- High quality and volume of the accommodation and food base (19 sanatoriums, 8 spa hospitals, numerous lodging houses, restaurants, bars etc.),
- Excellent urban layout of the spa - four spa parks, gardens, nature reserves,
- Wide promotion and advertisement.

Iwonicz Spa

Iwonicz Spa is located in the Outer Flysch Carpathians (Figure 1). Geothermal waters (around 20°C) occur within the Eocene sandstones and are currently produced by several abandoned oil wells (to 1000 m of depth). The TDS values vary from ca. 8 to 20 g/L. The brines represent the type Cl - HCO₃ - Na - Br - I and (CO₂ + H₂S). Because of their origin, the water reserves are non-renewable; thus, they must be exploited with special care.

Rheumatism, skin diseases, diseases of the motor, alimentary and respiratory systems, and many other illnesses are treated in this resort. Waters are used for drinking and bathing treatments (peat baths including), and also for curative and cosmetic salt extraction.

The first records of the use of warm springs in this locality date back to 1578 and 1630; when, they were recognised and described by the royal physicians. The first bathrooms were built in 1793 and the resort soon started to flourish. At the beginning of the 19th century, outstanding chemists and physicians provided favorable opinions about the great curative value of these waters. It was at the same time that suitable utilities and buildings for curative purposes were built. Some of them have survived to the present. In 1856, Jozef Dietel - professor of the Jagiellonian University, called Iwonicz a "prince of iodine waters." Iwonicz water was bottled and sent around the Europe. The first wells (400 - 600 m deep) supporting the existing springs were drilled at the end of the 19th century. Warm brine discharged by one of them has been used to now. With time, the former springs vanished; thus, the exploitation started from the abandoned oil wells (Sokolowski, et al., 1999).

The interwar period was a real boom for Iwonicz. Also, at present, this is one of the best known and most frequented Polish resorts. At present, over 30,000 patients and tourists per year visit Iwonicz Spa.

FURTHER PROJECTS

Besides the existing structures, there are plans to build new geothermal health and recreation spas. Some projects await development, and several ones are in the process of design. The popularity of so-called water centers, several of which have already been successful, raises the interest to build more such facilities. In general, the centers will be one of the elements of integrated or cascaded geothermal systems. They are designed to use waters from deep and shallow wells, or thermal energy stored in shallow underground horizons, often with additional use of heat pumps and other renewables (i.e., solar). They include, among others, a geothermal station under construction in Zakopane, as well as several others that are planned (i.e., Poddebice).

Zakopane and Podhale Region

Zakopane is located in the southern Poland (Figures 1 and 2) on the slopes of the Tatra Mountains. (the highest part of the Carpathians). The Tatras, Zakopane and the Podhale region, due to their natural characteristics, constitute the main center of tourism and winter sports in Poland.

Over three million tourists visit this place each year. In the last years, the construction of a large-scale district heating system and other types of direct geothermal utilization were started here (Kepinska, et al., 2000) including balneo-therapy and bathing, because there is a great demand for water and geothermal centers.

The main geothermal artesian aquifer occurs in the Eocene and Mesozoic carbonates (depths of 1-3.5 km). The reservoir temperatures reach up to 80-100°C; flowrate from a single well 55-150 L/s; TDS of 0.1-3 g/L; wellhead static pressure 27 bar. Over 10 geothermal wells have been drilled within this area so far. All of them produce waters which have curative properties suitable in the dermatological, rheumatic, and endocrinological diseases; apart from this, they can be used as an adjunctive treatment for patients with contagious diseases.

The tradition of using warm waters for bathing is connected with Jaszczurowka – a suburb of Zakopane. A 20°C natural spring existing there was scientifically described in 1844. Hydrogeologically, this was an ascending spring outflowing along the regional fault which delineates the northern border of the Tatra Mountains. The warm spring in Jaszczurowka had been used by the local highlanders long before the middle of the 19th century.

In the interwar period, the 1920s and 1930s, Jaszczurowka flourished. The warm spring, two pools and the subsidiaries existed in Jaszczurowka until the 1960s. There were plans to modify the place and adjust it to balneological and therapeutic treatments. Unfortunately, after drilling a well which was to raise the spring's output, due to the mixing with cold waters from the neighbouring stream, the warm spring disappeared. In the 1970s, a small geothermal bathing center was established in the center of Zakopane. It uses warm (26 - 36°C) waters from two wells. In the summer, this place is flooded with tourists.

There are exceptionally great possibilities to build water centers in this region. In fact, every locality where there are wells discharging geothermal waters up to 80 – 90°C, can have its own geothermal center tailored to the needs of both the inhabitants and tourists (Figure 2). These can not only be large but also smaller centers fitted into the local architecture and landscape. There are two finished projects, one of which has just started to be developed in Zakopane (population 30,000) – the main city of the region. It will be one of the most modern geothermal water centers in Poland, and was created on the site of the above mentioned swimming pool, which existed since the 1970s.

The project provides for the construction of a complex for rehabilitation and recreation offering a full range of treatments and services. This will include outdoor and indoor swimming pools. The plans also include the building of a conference center as an integral part of the complex. The facility will serve 1000 people per hour. The investment will be financed from Polish sources, with the municipal administration as one of the shareholders.

This is a long awaited project, indispensable to broaden the tourist offer of the city and to improve the quality of recreation at the main tourist center in Poland.

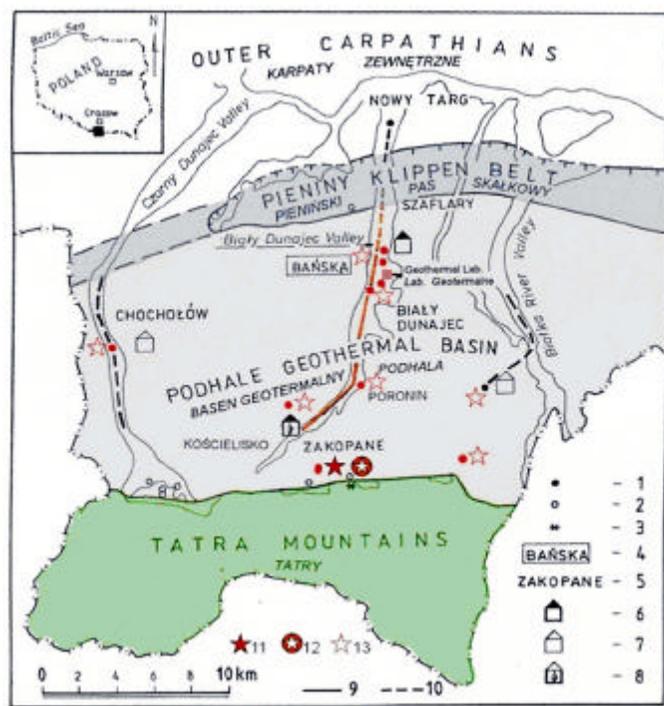


Figure 2. *The Podhale region, S-Poland: geothermal balneo-therapeutical and bathing centers and geothermal space-heating facilities .*

1. Geothermal wells, 2. other wells, 3. geothermal spring in Jaszczurowka (existing to the 1960s), 4. locality with geothermal space heating system on-line (2001), 5. localities planned to be geothermally heated (2001 – 2001), 6. geothermal base load plant (commissioned in 1998), 7. geothermal heating plants planned, 8. central peak heating station (commissioned in 1998), 9. main transmission pipeline, 10. transmission pipelines planned, 11. geothermal bathing center on-line, 12. geothermal bathing center under construction (2001), 13. possible locations of geothermal balneo-therapeutical and bathing centers Poddebice.

Poddebice

The town is located in the Central Poland (Figure 1). This area constitutes the relaxation and solace base for the inhabitants of Lodz – the second largest, after Warsaw, agglomeration in Poland. In Poddebice and the surrounding areas (just as nearby Uniejów which has geothermal prospects, too) are within the area of the occurrence of the Cretaceous sedimentary formations – one of the most promising geothermal aquifers in the country. In this area, reservoir temperatures amount to 70 - 80°C, geothermal waters characterise with TDS up to 60 mg/L. (Sokolowski, 1993; Ney, 1995; Gorecki, 1995). The waters have high curative and healing properties.

Poddebice is an example of a medium size town (population around 8,000) and county, which is dynamic and aims at the development of new spheres of balneo-therapy, tourism and recreation in the area with no such traditions in the past. Thanks to a convenient location in Central Poland and the qualities of geothermal waters, Poddebice has the chance of becoming a modern, regional center of balneology and relaxation on the grounds of the warm waters.

The town and county have already developed feasibility studies and technical projects of complex geothermal energy use for heating, curing and recreation purposes. Now they are trying to obtain suitable financial

means and find investors. As far as balneology and recreation go, there are plans to establish a large local hydrotherapy center. The project was highly rated by the renown Polish and foreign medical experts. The waters will be delivered from new wells which have to be drilled. At present (2001), the construction of a modern hospital is underway where about 800 treatments will be done every day. A sports and recreation center will also take advantage of the waters. The biological rejuvenation center will complement the medical functions of the balneo-therapeutical hospital.

The existence of the new geothermal center will cause the development of a hotel base, services, agro-tourism and economy infrastructure, as well as - which is very crucial - influencing unemployment by creating new jobs.

In Uniejów - located about 10 km from Poddebice, a geothermal heating network is being built and in the future the construction of bathing and balneology center will take place.

CONCLUSIONS

Although not numerous, geothermal spas offering curative and recreation services are an important element of health resorts in Poland. They have a long and interesting history. There is a growing need for this type of services, as well as an increased interest of potential investors.

In the recent years, together with the projects of a comprehensive usage of geothermal energy in Poland, there occurs opportunities to develop new spas and water centers. They can be created near the largest city agglomerations in the country, which are political, economical, and business centers. Such centers express a great and constantly growing need for recreation, biological rejuvenation and treatment services. These facts are an important stimulus for the creation of new water centers, that should raise the interest among investors and also generate financial benefits.

Geothermal therapy and recreation is a promising line of business with great opportunities for development in Poland; although, they are not fully understood and exploited. One of the limitations of a wide and adequate development is still insufficient promotion and funds.

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REFERENCES

- Dowgiallo, J., 1991. "Geothermal Systems of the Sudetes." *Publs. Inst. Geophys. Pol. Acad. Sc., A-19 (236)*. Warszawa.
- Dowgiallo, J., 1976. "The Sudetes Thermal Waters." *Acta Geol. Pol.*, Vol. 26, No. 4.. Warszawa, pp. 617– 642 (in Polish, English summary).
- Dowgiallo, J., 2000. "Thermal Water Prospecting Results at Jelenia Góra – Cieplice (Sudetes, Poland)\ Versus Geothermometric Forecasts." *Environmental Geology* 39 (5) March. Springer-Verlag.

- Gorecki, W., Editor, 1995. *Atlas of Geothermal Energy Resources in the Polish Lowland*. Krakow.
- Gorecki, W., Editor, 1998. "Poland." *Atlas of Geothermal Resources in Europe*.
- Kepinska, B., 2000. "The Podhale Low-Enthalpy System: Geothermal Characteristics." *Proceedings of the World Geothermal Congress 2000, Japan*.
- Kepinska, B.; Bujakowski, W. and R. Ney, 2000. "Geothermal Energy Country Update Report from Poland." *Proceedings of the World Geothermal Congress 2000. Japan*.
- Krawiec, A., 1999. "New Results of the Isotope and Hydrochemical Investigations of Therapeutical Waters of Ciechocinek Spa." *Prz. Geol. Warszawa* (in Polish, English summary).
- Ney, R., 1995. "Outline of Geothermal Conditions of Poland and Regional Geothermal Basins." *Bull. Polish. Acad. Sc. Earth Sci.* Vol. 43, no. 4. Warszawa.
- Sokolowski, J., 1993. "Geothermal Resources of Poland and Possibility of Their Utilisation in Environmental Protection." *Exploration Technology, Geosynoptics and Geothermal Energy*. No 5-6. Krakow, pp. 67-80.
- Sokolowski, J., Editor, 1995. *Geothermal Provinces and Basins in Poland*,. Krakow, 124 pp.
- Sokolowski, J.; Sokolowska J. and B. Kepinska, 1999. "Using Geothermal Energy in Poland The Passing Millenniu." *Stories from A Heated Earth. Our Geothermal Heritage*. Cataldi, R., Hodgson, S. and J. Lund, Editors. GRC, IGA. Sacramento, California.



Figure 3. Ladek Spa – main balneo-therapeutics station named Wojciech (Source: Internet page www.ladek.pl).



Figure 4. Ladek Spa – one of indoor curative pools using warm water discharged by a spring (Source: Internet page www.ladek.pl).



Figure 5. Duszniki Spa – natural warm spring named Pienawa Chopina (Source: Internet page www.duszniki.pl).



Figure 6. Ciechocinek Spa – wooden cooling tower for spraying brines and creating an ocean-like microclimate (Source: Internet page www.ciechocinek.pl).