Available online at www.HEFJournal.org

Journal of
Human, Earth, and Future

Vol. 1, No. 1, March, 2020

Groundwater Mining in Contemporary Urban Development for European Spa Towns

Piotr Langer [1*]

[1] *Chair of Spatial Planning, Urban and Rural Design, Faculty of Architecture, Cracow University of Technology, 24 Warszawska Str., 31-155 Krakow, Poland*

Received 05 January 2020; Revised 21 February 2020; Accepted 25 February 2020; Published 01 March 2020

Abstract

Mining activity is usually associated with heavy industry, the degradation of space, and areas with a clear industrial character. In fact, mining can be associated with other functions such as health resorts, recreation, and leisure. In the case of spas specializing in balneotherapy, medicinal underground waters "mineral and thermal" are extracted from local deposits using mining methods in borehole mines. Mining activity is not the main direction of development of these places, but it remains absolutely essential for maintaining the spa function and offering services in the field of recreation, rest, and tourism. The article focuses on the relationship between mining activity and the basic function of spas; the spatial relations between urban development and the spa zone; the range of mineral and thermal water use (natural resources obtained from underground deposits using the borehole method); and above all; the manner of exposing mining facilities in spa space and explaining the importance of these elements. The basis for the discussion featured in the article is constituted by the results of an original study carried out by the author, employing field research, in 2018 at the Institute of Cities and Regions Design, Faculty of Architecture of the Cracow University of Technology. Research work was performed in a dozen South-German statutory spas (Baden-Württemberg, Bavaria, and Saxony). Four cities representing a much wider group of spa centres were selected for detailed analysis: Bad Buchau, Bad Saulgau, Bad Aibling, and Bad Schandau. It was shown that the selected cities were directly related to the mining of groundwater but, at the same time, differed significantly in terms of the studied features. The study's conclusions may be useful in programming the development of spa towns operating on the basis of underground medicinal waters, as well as in the creation of concepts and projects on an urban and regional scale.

Keywords: Green Architecture; Spa; Landscape Design; Public Space; Groundwater Mining.

1. Introduction

Groundwater belongs to the group of resources that are commonly procured using mining methods all over the world. According to the provisions of Polish law that regulate mining operations [1], resources extractable by mining, and therefore resources of significance to the economy that are mined from the soil, include the following types of groundwater:

* Corresponding author: piotrlanger@pro.onet.pl

http://dx.doi.org/10. 28991/HEF-2020-01-01-01

- Medicinal waters[*];
- Thermal waters, i.e. waters that have a temperature of at least 20°C at the point of exiting its source;
- Brine, water with a soluble mineral content that does not fall below 35 g/dm^3.

Medicinal thermal waters are a special type of groundwater, minable aquifers of which can be found all across the entirety of Europe. According to the state recorded at the end of 2014, as much as a third of the overall number of 50 thermal water aquifers present in Poland were medicinal water deposits [2]. In Germany, numerous medicinal thermal water aquifers are located in, among other places, the southern section of the country, which covers the foothills of the Alps in Baden-Wurttemberg and Bavaria [3], as well as in the Ore Mountains, on the German and Czech borderland.

Due to the broad possibilities of utilising groundwater, its economic significance is high and is constantly increasing[†]. Thermal groundwater is considered to be a renewable thermal energy source - and is primarily used in unconventional power generation, as well as in recreation and medicinal spa treatments as a therapeutic agent [5]. In the global consumption balance of the use of geothermal energy generated from groundwater, as much as 25 % of this energy is produced for the purposes of thermal spas with a recreational and medicinal function [5]. Quantitative tendencies of global geothermal heat consumption show a clear upwards trend. In the period between 1995 and 2015, the amount of energy generated from thermal waters all over the world increased five-fold, from a value of around 112 to almost 590 TJ/annum, with the recreational and medicinal spa sector noting an almost eight-fold increase. Global leaders in the production and use of thermal waters include the United States of America, China, Sweden, Germany, France, Finland and Canada [6-8].

Analogous tendencies can be observed in the mining and use of medicinal groundwater, including mineral waters. This is associated with a high level of mineral water consumption in developed countries, as well as the growing demand for medicinal waters in European regions in which spas that operate on the basis of groundwater are located. According to statistical data, the overall total consumption of mineral water in European Union member states has remained at a stable level for a number of years, only slightly exceeding the value of 100 l/person [9], with a clear upward trend visible in Poland[‡]. It is significant that in the overall balance of mineral drinking water in Poland, the highest share (over 55 % in 2013) is that of natural water - water that is mined from underground deposits using the borehole method [10].

2. Materials and Methods

The data that has been cited clearly points at the significant role of groundwater in the economy of European countries, including Germany. Thermal and medicinal waters currently constitute an important basis for the development and functioning of numerous regions, particularly spa regions. One example of such a region is the southern part of Germany, which includes the foothills of the Alps on the Austrian borderland and the Ore Mountains (Erzgebirge), which form a belt of borderland with the Czech Republic. In the southern part of the German states of Baden-Württemberg, Bavaria and Saxony there is a relatively large number of "Bad" statutory spas, which successfully conduct medicinal therapies based on the medicinal properties of locally-mined groundwater - either mineral or thermal, and in some cases also medicinal thermal waters.

The region was the subject of the author's field research conducted in August of 2018, as a part of the Institute of City and Regional Design of the Faculty of Architecture of the Cracow University of Technology.

The research project covered around a dozen southern German spa towns:

- In Baden-Wurttemberg: Bad Buchau, Bad Saulgau, Bad Schűssenried, Bad Waldsee;
- In Bavaria: Bad Aibling, Bad Endorf, Bad Feinlbach, Bad Heilbrunn, Bad Tölz, Bad Wiessee;
- In Saxony: Bad Brambach, Bad Elster, Bad Schandau.

[*] Depending on the content of soluble mineral compounds, elements or ions, the following waters are distinguished: ferriferous, fluoride-rich, iodiferous, sulphurous, siliciferous, radoniferous, as well as high and low carbon dioxide content waters; medicinal waters also include mineral waters with a total dissolved solids content that is not lower than 1000 mg/dm^3 [1] (art. 5).

[†] The increase in the significance of groundwater as a natural resource in Poland is proven by the change in legal regulations concerning mining property, which is regulated by law for selected mineral resources. In light of the mining law enacted in 1930, brines from medicinal mineral water sources were exempted from mining ownership which, as a rule, is the exclusive privilege of the state and is attributed to land ownership [4]. The geological and mining law currently in force, which was enacted in 2011 [1], considers medicinal and thermal waters, as well as brines, to be mineral resources that are covered by mining ownership of the State Treasury. This is clear proof of the acknowledgement of groundwater as a natural resource of potentially high economic significance.

[‡] In the years 2008–2013 the increase in mineral water consumption by the average Pole amount to around 19 litres [9].

Over the course of the study, particular attention was focused on selected matters and problems of the selected spa towns, particularly those concerning:

- The significance of groundwater mining to the development of other sectors of activity in the towns, particularly spa treatment as well as recreation and tourism;
- The role of mining structures in creating the utilitarian and aesthetic attractiveness of health resorts;
- The impact of activity associated with the use of groundwater on the spatial development of the towns and the spatial relationships between urban development and the health resort zone.

The field research was based on performing analyses of the extant state, including an identification of the direction and scope of the use of groundwater and determining the spatial and compositional relationships between structures associated with groundwater mining and use with the remaining elements of the urban structure, particularly historical old town areas. Over the course of the work, an extensive photographic documentation was collected, cartographic and planning materials were analysed, as well as information materials that are commonly made available at public and commercial buildings that base their operation on groundwater.

3. Results: A General Overview of Selected German Health Resorts

From among all of the investigated towns located in the southern part of Germany, four health resorts were selected for detailed analysis: Bad Buchau and Bad Saulgau (Baden-Wurttemberg), Bad Aibling (Bavaria) and Bad Schandau (Saxony) - as representatives of a broad group of the health resort towns of the entire region.

a. **Bad Buchau** is a small town located around 50 km to the north of the shore of Lake Constance, close to the point where the borders of Germany, Austria and Switzerland converge at a single location. The most important elements of its urban structure undoubtedly include the historical old town with a centrally-placed market square and the nearby castle grounds, in addition to health resort areas and structures located in the old town's vicinity, connected with the market square by a short promenade. The Bad Buchau health resort essentially covers a complex of clinics that offer therapy that aids in rehabilitation and the treatment of conditions and injuries treated by orthopaedics, rheumatology, urology and oncology [11, 12]. The primary medicinal factor are medicinal thermal waters with a temperature of 47.5°C that have been mined from the "Adelindis" spring since 1989. Apart from its operations as a sanatorium, the Bad Buchau health resort also others recreational baths, as well as hotel and gastronomic services, in addition to cosmetic and spa care treatments. The baths park of Bad Buchau fulfils the role of its main area of public greenery, whose most important element is a small lake along with the layout of walking paths that surround it (Figure 1).

Figure 1. The primary health resort space of Bad Buchau – a complex of rehabilitation clinics against the background of a lake, which is an element of the health resort park

b. **Bad Saulgau,** located only around a dozen kilometres away from Bad Buchau, is significantly larger. The health resort is located in the western part of the downtown area (Figure 2), at a distance of around 1 kilometre. It is also spatially separated from the old town's structure. In the health resort zone we can distinguish three functional sections: rehabilitation clinics, a complex of thermal baths with a medicinal and recreational function, as well as a park that integrates the entire complex. The health resort's park layout is a particularly significant attraction. It was designed in the form of a contemporary garden, whose composition is based around a shallow canal that forms a longitudinal axis. The landscaped park greenery is closely tied with open areas that feature an education and walking trail.

Figure 2. The densely-placed downtown development of Bad Saulgau

c. **Bad Aibling** is a Bavarian health resort located around 50 km to the south east of Munich and almost 40 km from the Alpine border with Austria. The town has a population of over 18 thousand inhabitants and is clearly the largest of those analysed in the study. The densely built-up historical centre with an irregularly-shaped market square (Figure 3) as well as a church that towers above the old town stand out from its urban structure. The health resort, along with a spa park, is situated on the south-eastern side of the downtown area. The sanatorium complex primarily includes clinics that offer medicinal therapies with the use of groundwater that is sourced at the health resort. The attractiveness of Bad Aibling as a health resort and tourist destination also stems from the value and assets of the entire region. A short distance away there are other Bavarian health resort town, such Bad Endrof (30 km) and Bad Tölz (45 km), in addition to rest and recreation destinations that are known all over the country, primarily the region of Lake Chiemsee (40 km).

Figure 3. Bad Aibling - view of the main square in the historical old town

d. **Bad Schandau** is the only health resort located in Saxony from amongst those analysed in the study, and is therefore located in south-eastern Germany. The town is located very close to the border with the Czech Republic and around 30 km away from Dresden, on the Elbe River, among the forested hills of the Eastern Ore Mountains (Osterzgebirge). The urban structure has a spindle-like form, inscribed into a narrow river valley (Figure 4). Health resort grounds and structures, including the health resort park, which has a linear layout, are concentrated around a small confluence of the Elbe (Kirnitzsch), near the mouth of which a modern thermal baths complex has been placed, with both a medicinal and recreational function. The Bad Schandau health resort specialises in balneotherapy, particularly Kneipp's therapy, utilising locally-mined hot mineral waters that were discovered in Bad Schandau at the turn of the eighteenth and nineteenth centuries. The historical tram line connecting Bad Schandau with the nearby, Lichtenheiner" waterfall is a peculiar attraction, constituting one of the features of the Saxon Switzerland National Park.

Figure 4. Panorama of downtown Bad Schandau from the side of the baths park, at the mouth of the Kirnitzsch River, a confluence of the Elbe

4. Discussion: Mining Function vs. The Operation of Health Resorts

The health resort towns that have been characterised above currently function and develop on the basis of medicinal groundwater. All of these health resorts possess the status of "Bad", which, according to German law, means that they conduct medicinal therapeutic activity by using locally procured resources. The sourcing of water is conducted using mining, by employing the so-called borehole method, and therefore directly from underground aquifers, which ensures that the waters are of the highest purity and that their positive health properties are maintained [13, 14]. In this context the link the connects Bad Buchau, Bad Saulgau, Bad Aibling and Bad Schandau with mining is obvious - groundwater extraction sites, which, for all intents and purposes, should be considered borehole process mines, and therefore structures that are closely tied with the extraction of a natural resource - mining - operate either inside or in the immediate vicinity of these towns. At the same time, the aforementioned towns are important centres of medicinal spa treatment, for which mining is necessary, yet remains secondary in relation to therapeutic and rehabilitation operations and various services related to rest, recreation and tourism.

The author's analysis of the selected health resort towns located in the southern part of Germany pointed to various forms and scope of exposing and explaining elements of borehole mining within urban space. In the case of Bad Buchau, the main entrance hall to the clinic complex features a small exhibition, whose main element is the drilling bit of a mining machine used in the drilling of groundwater extraction boreholes (Figure 5). Near the display case with the drilling bit, a brief overview of the geological makeup of the aquifer was presented, a historical overview of the borehole mining of groundwater from the “Adelindis” spring, as well as the detailed mineralogical makeup and physical properties of the mineral waters that are mined. The aspect of mining therefore appears in Bad Buchau in an educational and informative role, as well as an essential element of interior decoration in the most important health resort building.

Similarly as in Bad Buchau, attempts at exposing the function of mining in the space of the health resort were also made in Bad Saulgau. Mineral water mined using the borehole method from the local deposit is primarily utilised as a medicinal agent, but it also constitutes the fundamental element of the development of the spa park that accompanies the town's sanatorium structures. As it has been mentioned previously, the main feature of the contemporary park layout is a water canal in the form of a winding shallow waterway fuelled by medicinal waters (Figure 6). The specific micro-climate that forms around the canal is conducive to the introduction of plant species that are not present in the local natural environment. The water temperature is appropriate for medicinal and recreational purposes, but it also makes it possible to populate the waterway with exotic fish species. The spa park with the artificial canal is the start of an educational and sightseeing path named “Thermalwasser-Pfad”. The path has a length of around 1.5 km and includes a total of nine sites with information plaques devoted to matters of geology, geophysics, geochemistry and geological engineering. One of the problems that it describes is the link between the region's geological conditions with mining and the procurement of groundwater for use by the local health resort.

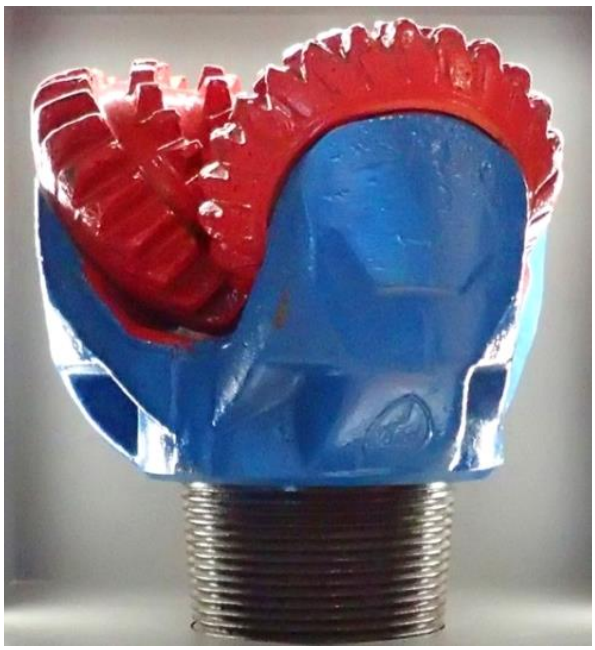

Figure 5. The drilling bit of a mining machine used to drill boreholes for the extraction of groundwater in Bad Buchau in the form of an exhibit in the entrance hall of the health resort complex

Figure 6. The interior of the spa park in Bad Saulgau. The main element of the layout's composition is a canal fuelled by thermal water procured for the health resort

Atypical actions in terms of exhibiting mining-related matters in urban spaces were taken in the Bavarian town of Bad Aibling. Spa buildings along with a park were placed in the immediate vicinity of the medicinal water extraction site, which is, in essence, an active borehole mine. The borehole used to access the aquifer is located near to the entrance zone of a complex of clinics and the main parking lot - in a generally accessible space, that is visited by practically all of the persons who make use of the health resort's offering. The borehole mine, whose primary element is a series of pumps that propel mineral water from the aquifer, has the form of a small building, which stands out from the surroundings with a simple architectural form and dark green colour scheme (Figure 7). From the side of the public space the building's facades are fully glazed, making it possible to freely observe the operation of the machinery installed inside - the process of the extraction of water in the borehole mine. The building's role is more of a utilitarian and compositional rather than an educational one. The operation of the building is not explained in detail - there is no information that would directly point to its mining-related function - we can only identify it by carefully observing its interior.

Figure 7. The building housing the borehole used to extract mineral thermal waters in Bad Aibling. The building is located near the entrance zone of the health resort and makes it possible to observe the mining process of groundwater extraction

Bad Schandau represents a broader group of German health resorts in which the function of mining is not particularly exposed or highlighted in urban space. At the same time, locally extracted groundwater is used to a wide extent - both in medicinal therapies offered by the health resorts, as well as for recreational purposes. The contemporary complex of thermal baths used not only by patients, but also by numerous tourists, stands out in the structure of the town. Matters associated with mining, geology and geochemistry are only briefly mentioned in information brochures available in the main building of the baths - we can therefore assume that general awareness concerning these matters is rather limited. Mining elements are not particularly exposed in urban space, which means that they do not take an active part in shaping its attractiveness.

Figure 8. Entrance to the modern thermal baths building in Bad Schandau against a panorama of the historical part of the town

5. Conclusions

The author's original field research covered a total of around a dozen German health resort towns located in the Alpine region (Baden-Wurttemberg, Bavaria), as well as in the foothills of the Ore Mountains, in the borderland between Germany (Saxony) and the Czech Republic. In the predominant majority of the towns, therapy is conducted with the use of mineral and geothermal groundwater. Medicinal waters used in balneotherapy are directly extracted from local aquifers using the borehole method in borehole mines. Mining activity is therefore an inseparable element of the analysed health resorts - both in functional and spatial terms. There is no doubt that the primary function of these towns is that of providing medicinal spa treatments, supplemented by various forms of rest, recreation, and tourism. The health resort zone with a park is also a key spatial element, of visual and compositional significance comparable only to historical town centres. At the same time, mining remains secondary and subjected to the function of the health resort, although it is absolutely necessary for a town to be able to offer services that rely on groundwater.

An issue that is highly significant to health resort towns emerges against this background - that of the role of mining structures, particularly borehole mines that extract medicinal waters from aquifers, in the creation of the

utilitarian and aesthetic attractiveness of the health resorts themselves. While discussing this problem, four selected health resort towns were subjected to a detailed analysis: Bad Buchau, Bad Saulgau, Bad Aibling, and Bad Schandau - all of which are associated with medicinal water mining but that are nevertheless somewhat varied in terms of size and spatial layout.

Over the course of the research work, it was demonstrated that the scope of using mining to support and supplement basic forms of use (i.e., medicinal spa treatment, rest and recreation), in addition to the manner of exposing and describing the mining function in urban space, is an essential characteristic that differentiates the analysed towns. The example of the health resort in Bad Aibling demonstrates that a borehole mine, as an industrial structure, can harmoniously blend into the greater urban structure, have a contemporary form featuring high aesthetic and material standards, as well as belong to a generally available public space. In turn, in Bad Saulgau, thermal groundwater - a locally mined natural resource - was used as the main material for the attractive space of its health resort park. Its artificial canal is not only the primary element of the composition of an entire garden complex, but also constitutes the foundation of a walking and educational path that links the health resorts with their surrounding open areas. Mining activity can therefore be accompanied by educational and even scientific value, associated with the presentation and explanation of problems and phenomena from the fields of geology, geophysics, geochemistry, and geomechanics, as well as methods of extracting natural resources and various aspects of the impact of mining on space. Elements of mining are also legible in the Bad Buchau resort, as a part of an exhibition in its clinic's main entrance hall; they fulfil an informative and aesthetic role in the interior's arrangement.

The examples that have been mentioned prove that mining activity and its associated structures can significantly improve the attractiveness of urban space or can supplement a primary form of use, which in this case is providing medicinal spa treatments and recreation. At the same time, the analysis of Bad Schandau demonstrated that mining was not exposed or highlighted in any particular form in a certain group of health resorts that base their operations on groundwater. This function was seen to be merely mentioned in information brochures available in public and commercial buildings. According to the author, the marginalisation of the significance of or completely ignoring mining elements is not conducive to the improvement of the aesthetic and utilitarian attractiveness of some health resort towns—mining activity remains necessary there, although it does not carry with it any significant added value.

6. Declarations

6.1. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.2. Funding

The author received no financial support for the research, authorship, and/or publication of this article.

6.3. Institutional Review Board Statement

Not applicable.

6.4. Informed Consent Statement

Not applicable.

6.5. Declaration of Competing Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the author.

7. References

[1] Lipiński, A., & Lipińska, K. (2011). New Polish Geological and Mining Law. Polish Yearbook of Environmental Law, (1), 57-84. Available online: https://apcz.umk.pl/czasopisma/index.php/PYEL/article/viewFile/PYEL.2011.004/343 (accessed on January 2020).

[2] Socha M., (2016). Potential and prospects for the use of geothermal resources in Poland, Association of Polish Poviats, Warsaw, Poland.

[3] Machoń, K. (2012). Ciepłownictwo geotermalne w Niemczech. Technika Poszukiwań Geologicznych, 51, 11-22. Available online: https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-article-BPZ3-0042-0021/c/httpmeeri_plwydawnictwatpg2012-1cz-01-02-machon.pdf (accessed on December 2019).

[4] President.pl (2020). The official website of the President of the Republic of Poland: Ordinance of the President of the Republic of Poland of the 29th of November 1930, Mining law, Poland.

[5] Sala, J. (2017). Wody geotermalne jako czynnik rozwoju turystyki w regionie Podhalańskim. Prace i Studia Geograficzne, 62(2), 87–103.

[6] Lund, J. W., & Boyd, T. L. (2016). Direct utilization of geothermal energy 2015 worldwide review. Geothermics, 60, 66–93. doi:10.1016/j.geothermics.2015.11.004.

[7] Araujo, A. R. T. S., Sarraguça, M. C., Ribeiro, M. P., & Coutinho, P. (2016). Physicochemical fingerprinting of thermal waters of Beira Interior region of Portugal. Environmental Geochemistry and Health, 39(3), 483–496. doi:10.1007/s10653-016-9829-x.

[8] Sowiżdżał, A., Hajto, M., & Hałaj, E. (2020). Thermal waters of central Poland: a case study from Mogilno–Łódź Trough, Poland. Environmental Earth Sciences, 79(5). doi:10.1007/s12665-020-8855-2.

[9] Kłos, L. (2016). Spożycie Wody Butelkowanej w Polsce i jej Wpływ na Środowisko Przyrodnicze. Barometr Regionalny, 14(1), 111-117.

[10] Ordinance of the Minister of Health and Welfare of the 8th of July 1997 on the matter of specific sanitary conditions in the production and handling of natural mineral waters, mineral mixed waters, natural spring waters and table waters, Poland.

[11] Tourist-Information Center Bad Buchau (2020). Promotional materials available in the health resort buildings of Bad Buchau, Germany. Available online: https://www.bad-buchau.de/fileadmin/Dateien/Dateien_pdf/G%C3%A4ste/Flyer_Buchau_Englisch_klein_rgb.pdf (accessed on February 2020).

[12] Carbajo, J. M., & Maraver, F. (2018). Salt water and skin interactions: new lines of evidence. International Journal of Biometeorology, 62(8), 1345-1360. doi:10.1007/s00484-018-1545-z.

[13] Karpińska, M., Kapała, J., Raciborska, A., & Mnich, S. (2019). Assessment of Effective Dose from Radioactive Isotopes Contained in Mineral Waters Received by Patients During Hydrotherapy Treatments. Water, 12(1), 97. doi:10.3390/w12010097.

[14] Corniello, A., Ducci, D., Ruggieri, G., & Iorio, M. (2018). Complex groundwater flow circulation in a carbonate aquifer: Mount Massico (Campania Region, Southern Italy). Synergistic hydrogeological understanding. Journal of Geochemical Exploration, 190, 253-264. doi:10.1016/j.gexplo.2018.03.017.