Balneological prospects in Iceland using geothermal resources

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Abstract

Balneotherapy has been practiced all over the world from early history. In Iceland bathing in geothermal pools was popular for recreation from early settlement some 1100 years ago. The Icelandic Sagas written in the thirteenth century report the use of geothermal bathing for balneotheraphy to ease rheumatic pain. In modern Iceland the Health and rehabilitation clinic in Hveragerði and the Blue lagoon spa by the Svartsengi power plant are the main balneological resorts. Further prospects to build several spas and health resorts appear to be very promising in Iceland. The geothermal waters are of varied chemical composition, there are ample resources of uncontaminated spring water and clean air as well as magnificient scenery. Further there is access to geothermal clay and precipitates as aid in balneotherapy treatment. The local food supplies are also very fresh and free for contamination and the health care system is of high quality. More research is needed as well as enforced market survey and enforcement of the service needed for the varying market targets. Classification of Icelandic geothermal water reveals that sulfide water, fluoride water and saline waters are commonly encountered. Iron rich water is rather rare and iodide water and radioactive water has not been found. Mineral water suitable for drinking is not uncommon. Saline geothermal water resources encountered at several localities in Iceland bear resemblance to that of famous Spa localites as Baden-Baden in Germany. Among those are Seltjarnarnes, a suburb of the capital city Reykjavík, the small towns Stykkishólmur and Húsavík as well as some localities in rural areas of the country.

Keywords: *balneology, balneotheraphy, geothermal pools, classification of Icelandic geothermal water, spa, resources.*

1 Introduction

There is a long tradition in Iceland for the use of geothermal baths as entertainment, relaxation and also for rehabilitation and curing of rheumatism and other illnesses. There has been an interest for a long time to build out the tourist industry to include balneotheraphy (Checci and comp., 1975), but so far there has been a rather slow growth rate and no big projects have been launched in the last years in spite of considerable interest of the government and private investors.

Geothermal activity is widespread in Iceland (Björnsson et al., 1990) and the resources are varied both in temperature and chemical properties. The geothermal fields are classified as high-temperature geothermal fields and low-temperature geothermal fields according to the base temperature at 1 km depth. The high-temperature fields have temperatures exceeding 200 °C , but below 150 °C in the low-temperature geothermal fields.The high-temperature geothermal fields are all located within the active volcanic zone and closely related to volcanic centers, whereas the low-temperature fields are found in older geologic settings.

There are available data of the chemical compostion of spring water, gas and steam from fumaroles and fluids from wells from most of the geothermal fields in the country (Kristmannsdóttir, 1990, 1992). The data span over long time interval and are of varying quality, some are published and some are contained within official and privately owned data banks. Data of cold water are much more scarce as many of the private and municipal waterworks are fairly small and have not had the means to make chemical analysis of the waters according to quality assurance criteria.

The first step in building up a balneological industry is to define the resources, physical and social. This entails the classification of geothermal waters, checking the availabilty of mineral water, clay deposits and geothermal precipitates, the purity of the air and potable water as well as the available medical service, and recreation. The next steps are to make market analyses and then to define business projects based on results from those two primary steps. A part of the resource definition as well as the definition of a business project is to designate the kind of balneoteraphy possible for the type of waters and other resources accessible. This requires a close cooperation of specialists from different fields; geoscientists, medical doctors and people educated in economics. In this paper an effort to classify the resources is described and some primary steps taken on the way to maket analysis and project definitions.

2 Chemistry of icelandic geothermal waters

Geothermal water in Iceland is in most cases of meteoric origin and only in a few places sea-water originated. In general the salinity of Icelandic groundwaters is in direct relation to the distance from the ocean (Fig. 1) The low-temperature geothermal waters are generally very diluted, with typically 200-400 mg/l, of dissolved solids (TDS) and gases, but the mineralization increases by increased reservoir temperatures. In the non-saline high-temperature geothermal waters TDS exceeds 1000 mg/l. A few fields are either sea-water contaminated or the waters seep through sediments formed in sea-water. Their salinity is most commonly less than 10 % that of of sea-water. On the Reykjanes peninsula, in SW Iceland and in Öxarfjördur in NE Iceland (Fig. 2) there occur waters with much higher salinity, up to that of normal sea-water (Kristmannsdóttir and Ólafsson, 1989).

The dominant reservoir rocks in the Icelandic geothermal fields are basaltic lavas and hyalo-clastites and the fluids evolved by reaction with such rocks at elevated temperatures have high pH values. Acidic igneous rocks are encountered within the central volcanoes, past and present, but account to about 10 % of the total volume of rock formations in Iceland.

The pH values are typically 9-10 for the low-temperature waters, but lower for the high-temperature geothermal waters due to their higher concentrations of acidic gases. Waters with extremely high pH, about or even exceeding 11 are also encountered, especially on the boarders of the active volcanic zones in SW and NE Iceland where young, glassy, basalt lavas, which are highly reactive, are common in the underground reservoir rocks (Fig. 3). The geothermal waters are in equilibrium with silica minerals, alkali-, iron-, magnesium and aluminium silicates, calcium carbonate and metal sulfides and oxydes (Arnórsson et al., 1983, Kristmannsdóttir, 1990). The silica concentration of the waters is in direct relation with increasing temperature, carbonate concentration is in inverse relation to increasing temperature and the waters are highly depleted in magnesium, even at moderate temperatures. The waters are devoid of dissolved oxygen and the gas phase is mainly constituated of nitrogen and minor argon as well as carbon dioxide and hydrogensulfide. Waters reacting with acidic rocks will contain somewhat higher chloride concentration than those reacting with basaltic rocks and also have higher concentrations of fluoride, boron, lithium and radioactive elements. In general all the elements, which are not bound in the minerals of the basaltic rocks, will be concentrated in the acidic rocks and hence in the waters reacting with them. Other elements as iron, manganese, copper, cobolt and zink will be more enriched in the basalts and therefore also in the waters reacting with such rocks. The mineral concentrations of the waters will also be highly dependent on the age and weathering and alteration state of the rocks.

The high temperature geothermal waters are much more mineralized due to increasing solubility by increased temperature of most of the minerals determining the water-rock equilibrium in the geothermal systems. As in the case of the low-temperature waters there do exist geothermal brines, mainly on the Reykjanes peninsula. Reaction with basaltic and acidic rocks affects the high-temperature geothermal waters in a similar way as at lower temperatures. The high-temperature geothermal fields offer a great variability in water chemistry of associated spring water by the addition of steam to either the boiled and cooled geothermal water or to cold spring water. By the variation of those components waters with a range of pH and mineral concentration can be created.

3 Balneological classification of Icelandic waters

The Icelandic geothermal waters have been classified by their chemical character and balneological properties (Kristmannsdóttir et al., 2000, 2001) using a classification slightly adapted for Icelandic conditions but based on both German (Fresnius and Kuβmaul, 1998) and Japanese (Agishi et al., 1995) classifications for health resort water.

The classification groups are:

1. Carbonate water containing total carbonate (calculated as CO_2) in excess of 300 mg/l
2. Sulfide water containing H_2S in excess of 1 mg/l and of temperature > 40 °C.
3. Highly mineralized warm (>40 °C) waters with TDS (total dissolved solids) exceeding 1000 mg/l.
4. Iron rich water containing iron in excess of 20 mg/l and of temperature > 40 °C.
5. Fluoride water containing fluoride in excess of 2 mg/l and of temperature > 40 °C.
6. Iodide water containing iodide in excess of 1 mg/l.
7. Radioactive water containing radon in excess of 666 Bq/l .

In Iceland carbonate waters (Fig. 4), both thermal and cold waters, are most common in the Snæfellsnes peninsula (Arnórsson, 1982, Arnórsson and Barnes, 1983). The carbon dioxide of both the thermal and cold waters is believed to have a different origin from the waters and be derived from deep seated intrusions or the mantle. All high-temperature waters are carbonate waters. Carbon dioxide springs commonly occur on the outskirts of high-temperature geothermal fields and are formed by either mixing of hot and cold water or by steam heating of shallow cold groundwater.

The sulfide waters (Fig. 5) are encountered in all high-temperature geothermal fields and many low temperature fields especially in younger geological formations. The highly mineralized waters (Fig. 2) are either saline (brines), carbonate or high-temperature waters. Iron rich water is not common in Iceland and mostly associated with carbonate waters. Fluoride water is rather common (Fig. 6) and often associated with central volcanoes, high-temperature geothermal fields and acidic reservoir rocks. Iodide waters have not been encountered in Iceland. The radioactivity of the thermal waters has not been studied in any detail. Radon in Icelandic geothermal waters has been monitored in the aim to forecast earthquakes (Hauksson and Goddard, 1981) and to map the flow pattern in geothermal fields (Ármannsson et al., 1982). The limited data existing indicate a relatively low concentration of radon in Icelandic waters, which is not unexpected in light of the low concentration of radioactive elements in the Icelandic rocks (Poliakov and Sobornov, 1975).

A correlation between chemical classification and balneological properties is not always a straightforward task and it appears that in spas different water types have been used for the treatment of many diseases (Björnsson, 2000, Agishi et al., 1995). Balneotherapy is an alternative treatment often used for uncurable illnesses and when an effective medicine is discovered it will mostly replace the balneotherapy methods. Many Icelandic waters of the groups 1, 2, 3 and 5 above are similar to those of renowned foreign spas and have already proved to be effective in the treatment of skin diseases and reumatism. Further study of their effectiveness in treatment of other ailments remains to be made.

4 Other available resources

Hydrothermal clay deposits, silica precipates and steam sublimates, which are of importance for balneological uses, are usually readily available at the sites of high-temperature geothermal fields. The mining of hydrothermal clay in situ is usually rather difficult due to the inhomogenity of the deposits and mixing with other hydrothermal deposits. Some places like in Hveragerdi, which is one of the Hengill high-temperature fields, the clay has been redeposited and enriched and is therefore easily mined. There it has been utilized for a long time in Icelands oldest spa resort (Gunnarsson, 1998). Mapping of Icelandic clay deposits, hydrothermal and sedimentary, is still rather incomplete and needs to be enforced. Most places in Iceland there are ample resources of fresh and uncontaminated potable water, even though their documentation might be improved. Likewise the atmospheric air is clean, healthy and fresh. The nature is magnificent and the environment peaceful. The cousine is rather tasty and based on good and uncontamined local food provisions. The national health care system is good and in the larger towns there are high-tech hospitals providing first class treatment for all kinds of illnesses. The possibilities offered for recreation are ample.

5 Comparison with other countries

As compared to geothermal waters in other countries the waters in Iceland are generally much less mineralized although there are geothermal brines and highly mineralized waters in a few places (Fig. 2). The thermal waters in central Europa are much more highly mineralized than typical low-temperature geothermal waters in Iceland, but some low-temperature brines in Iceland are rather similar to water in many European health resorts like Baden Baden (Björnsson, 2000, Kristmannsdóttir et al., 2000). The existing data indicate that the concentration of radon in Icelandic waters is very low as compared to values in other European countries. Geothermal waters in Japan (Hotta and Ishiguro, 1986) are varied in composition and many are quite comparable in composition to waters in Iceland, especially in the high-temperature geothermal fields. Geothermal bathing is traditional in Iceland from early settlement some 1100 years ago and the Icelandic sagas written in the thirtieth century report “going to baths” as a popular entertainment and also as treatment to ease rheumatic pain. Nowadays the average Icelandair uses the swimmingpools as an everyday recreation and relaxation enjoying more numerous swimmingpools per capita than in any other country. Spa treatment however is not as popular nor common in Iceland as in many European and Asian countries.

6 Places of special interest

On basis of the primary market analyses and definition of some possible business projects based on the classification of geothermal waters, definition of other resources and appraisal of the kind of balneoteraphy possible for the type of waters (Björnsson, 2000) some places of special interest for the building of health spas have been pointed out.

All the high-temperature geothermal fields offer great variability in the possible water/bath composition as steam or condensate addition to the hot water or even to cold water will give a broad spectrum of different water composition. At the sites there will generally be ample deposits of geothermal mud, clay and silica deposits. The main places of interest are the ones located near densely populated areas like the Reykjanes, Svartsengi, Krísuvík and Hveragerði fields in SW Iceland and the Námafjall field in NE Iceland (Fig. 2). The Blue lagoon spa in the Svartsengi field (the Blue lagoon committee, 1996) has become one of the main touristic trademarks of Iceland and is renowned for effective treatment for psoriasis (Ólafsson, 1996). In Hveragerði the Health Clinic of the Nature health Association of Iceland was established in Hveragerdi in 1955 with preventive measures in view. “The clinic is only a short walk from the mineralrich, geothermal mud pools which provide the essential ingredient for its mud baths, a miracle in alleviating the joint pains common to arthritis." (Gunnarsson, 1998). Reykjanes and Svartsengi are brine fields whereas in the Krísuvík and Hveragerði fields the waters are not very saline. In northern Iceland the Námafjall high-temperature, freshwater geothermal field is a quite interesting site, beeing near great turist attractions, well known and studied and some balneotherapeutic development is underway at the site.

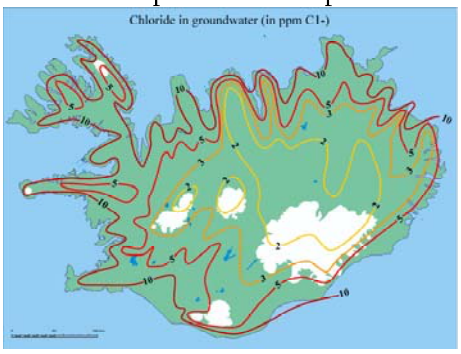

Figure 1: Chloride concentration in Icelandic groundwater (Sigurðsson and Einarsson, 1988).

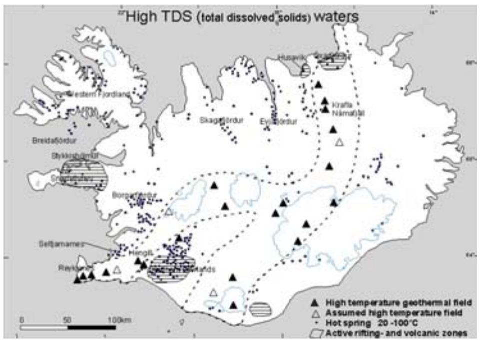

Figure 2: The main distribution of highly mineralized waters in Iceland.

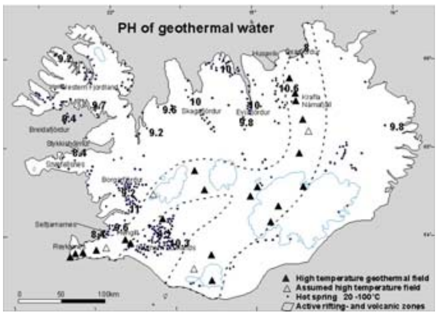

Figure 3: pH in selected typical low-temperature geothermal waters in Iceland.

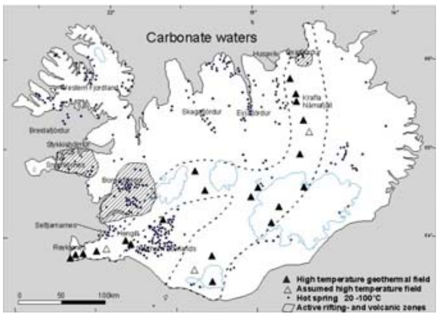

Figure 4: The main distribution of carbonate waters in Iceland.

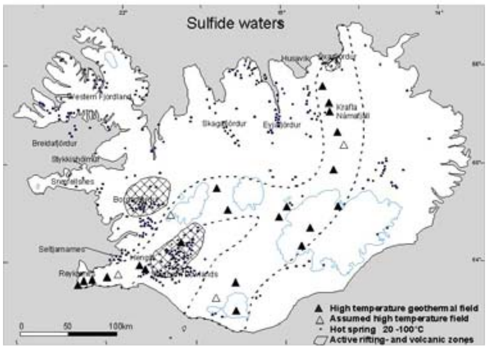

Figure 5: The main distribution of sulfide waters in Iceland.

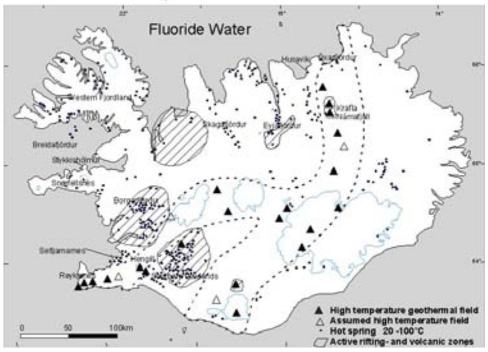

Figure 6: The main distribution of fluoride waters in Iceland.

Places with low-temperature brines are known especially on the Reykjanes and Snæfellsnes peninsula and in Öxarfjördur NE Iceland (Fig. 2). Near Húsavík (Figs. 2-6) in NE Iceland low-temperature geothermal brine has been used for the treatment of psoriasis. On the Snæfellsnes peninsula the small town Stykkishólmur (Figs. 2-6) utilizes similar low-temperature brine for heating and has been planning the outbuilding of a health resort in cooperation with the local hotel as well as the hospital. The water has been used successfully for the treatment of psoriasis and has been attested by Institut Fresnius in Germany as "Heilwasser" (Sturludóttir pers. comm.). It is claimed to be appropriate for health cures by drinking as well as for bathing therapy for rheumatism.

An interesting location within an urban area is the town of Seltjarnarnes (Figs. 2-6), one of the suburbs of the capital city Reykjavík, where ample sources of low-temperature brine of a similar type as the ones in Stykkishólmur and Húsavík are available.

There are several places with exessive water and special other attractions, like the Reykhólar field, north of the bay of Breidafjördur (Fig. 2-6) in western Iceland. There the water is fresh, just over 100 °C and available in ample quantities. The largest known sedimentary mud deposits in Iceland are found nearby. There are several tourist attractions in the area, which is also very scenic. In several of the islands in the bay of Breidafjördur south of the area there are springs with hot water of varying salinity. Places with carbon dioxide water and geothermal water available at the same site are not common. The Lýsuhóll field on Snæfellsnes is one of the few known places.

7 Conclusion

Prospects to build spas and health resorts in Iceland appear to be very promising. The geothermal waters are of varied chemical composition; there is access to geothermal clay and precipitates as aid in balneotherapy treatment and ample resources of uncontaminated spring water and clean air as well as magnificient scenery and numerous tourist attractions. The local food supplies are fresh and free for contamination and the health system in the country is of high quality. There have been pointed out several places of special interest for further study and market survey. Except for the Hveragerdi and Blue Lagoon Spas and for Stykkishólmur town the kind of balneoteraphy possible for the type of waters and other resources accessible have not been defined yet in any of the places considered promising for outbuilding.

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