DOI: 10.7251/JEPMEN1507055S
UDK: 620.91:497.6
Professional paper

GEOTHERMAL ENERGY OF THE REPUBLIC OF SRPSKA AND HYDROCHEMICAL ASPECTS OF ITS EXPLORATION AND EXPLOITATION

Andrijana Stevanović, Boban Jolović
a.stevanovic@geozavodrs.com

Geological Survey of the Republic of Srpska, 75400 Zvornik, Republic of Srpska, B&H

Abstract

One of the most used renewable energy sources worldwide is geothermal energy. It represents the heat, originated by natural processes happen in the Earth interior. The hot springs phenomena are the most frequent natural manifestation of geothermal activity.
Geothermal potentiality of some area can be estimated based on geothermal gradient. Geothermal gradient is a conductive terrestrial parameter that represents the degree of increasing of the Earth temperature vs. depth. It is usually expressed in ºC/m or ºC/km. Different areas have different thermal gradients and thus different geothermal potential. Generally, higher geothermal gradients correspond to areas containing more geothermal energy.
Geothermal characteristics of the territory of the Republic of Srpska are closely related to its complex geological setting. It is the reason why geothermal characteristics are different from area to area. Higher geothermal potentiality is recognised in the northern parts of the entity, in the first order in Semberija, Posavina and Banja Luka regions.
The use of geothermal energy with different fluid temperatures can be considered throughthe Lindal diagram, who firstly proposed acomprehensive scale with appropriate temperatures for different uses. High temperature fluids are mostly used for electricity production and moderate and low temperature fluids for the direct use.Despite the fact that the territory of the Republic of Srpska has favourable geothermal properties, utilization of this kind of renewable energy resource is inadequate. Especially indicative are data about the use of geothermal energy by heat pumps (in bad sense) in comparison with praxis of developed countries.

Chemical composition of thermal waters plays very important role and can be used in its exploration stage, for analyses of possibility of its use and for prediction of exploitation effects, as well. This kind of renewable energyresource, highly ecologically recommended, must be considered more seriously in the future in the Republic of Srpska. Furthermore, it must be put into the energy strategic documentsin appropriate manner.

Keywords: *geothermal, energy, sources, application.*

1. Geothermal energy – term, originationand its manifestationon the Earth surface

Geothermal energy represents the heat originated by natural processes happen in the Earth interior. In the last few decades prevailed opinion about heat sources in the Upper Mantle and lower part of ocean and continental crust dominantly from radioactive decay of ^{238}U, ^{232}Th and ^{40}K. In fact, in accordance with this hypothesis, isotopes of the above-mentioned elements are, due to differentiation, accumulated closer to the Earth surface – in the continental crust.
Under *KarstenPreuss*[7] fundamental heat source beneath the surface is the decay of instable radioactive isotopes, which occur in relatively small concentration in comparison with the Earth volume, especially in the crust. This heat is transmitted by different mechanisms to the surface, including conduction, fluid convection or via direct movements of melted rocks toward shallower horizons.
Hot springs and “mud pots” are natural phenomena caused by geothermal activity. Numerous locations of geothermal activities are visible on the surface worldwide, in the Republic of Srpska as well. Well-known are those in Višegrad, the Drinjačacanyon (Milići), Slatina (Laktaši), Laktaši, Šeher (Banja Luka), Lješljani, Teslić, Kulaši ,Sočkovac etc.

2. Geothermal resources, reservesand geothermal systems

*Geothermal resources*can be easily define as reservoirs in the Earth interior from which heat can be economically captured and used for electricity production or some other suitable application (industry, agriculture, household etc.).

Geothermal reservoirs can contain heat in the rocks or in fluids which fill their pore space. Estimations of geothermal resources are provided based on: 1) depth, thickness and distribution of geothermal aquifer; 2) characteristics of rocks; 3) salinity and geochemistry of fluid in an aquifer; 4) temperature, porosity and permeability of rocks [3].

Geothermal resourcesare differentfrom*geothermal reserves;* the second onerefers to a part of the resource which can be economically justified exploited on the current development of technology.

From the previously said, it is clear that sometimesfor geothermal energy exploitationit is not enough just to reach heated rocks with boreholes(except rocks with enough porosity and presence of fluid), but heat must be separated through some fluid circulation. It means that in non-porous heated rocks appropriate porosity must be created artificially and a fluid must circulate after it through pores.

The above-mentioned facts introduce us in the presence of different kinds of geothermal systems. The key elements for their existence are: 1) heat source; 2) a reservoir for heat accumulation and 3) presence of roof barriers which provide storage of heat in the reservoir.

Different geological circumstances, among other things, arethe reason for presence of different kinds of geothermal systems. Generally, the systems can be classified as follow:

-*Geothermal systems dominantly with vapour* (usually split into systems with wet and dry steam);

-*Geothermal systems with hot water*, which can be divided into: a) systems with low to moderate temperature (50-150^{o}C) and water chemistry similar to regional surface waters or groundwater), b) systems with a part of non-meteoric waters, which usually occurs in deep sediment basins; c) systems with presence of brines; d) systems with natural roof layer, usually fine grain sized, of low permeability; e) systems with self-created roof layers by chemical exchanges and deposition of sediments close to surface, in locations where temperature rapidly decrease [3].

-*Geopressured systems*, created mostly within the basins characterised by rapid sediments filling. It is a type of hydrothermal surrounding with hot water practically isolated from exchange with other rocks [3].

-*Hot dry rocks (HDR***),** generally may be divided on: a) systems connected with recent volcano activity; b) systems connected with high values of heat flow; c) localised radiogenic heat sources (as result of high content of radioactive minerals in rocks).

-*Magma*, did not have practical importanceyet.

2. Geothermal gradient – basic geothermal parameterfor estimation of an area geothermal potentiality

Geothermal gradient represents conductive terrestrial parameter as the degree of increasing of the Earth temperature vs. depth. It is usually expressed in ^{o}C/m or ^{o}C/km.Different areas have different thermal gradients and thus different utilization potential. Generally, higher thermal gradients correspond to the areas containing more geothermal energy. Taking into account the map of distribution of this geothermal parameter in the territory of the Republic of Srpska[5] it is possible to conclude about higher geothermal potentiality of the northern parts of the Republic of Srpska, in the first order in Semberija, Posavina and Banja Luka regions (Figure 1).

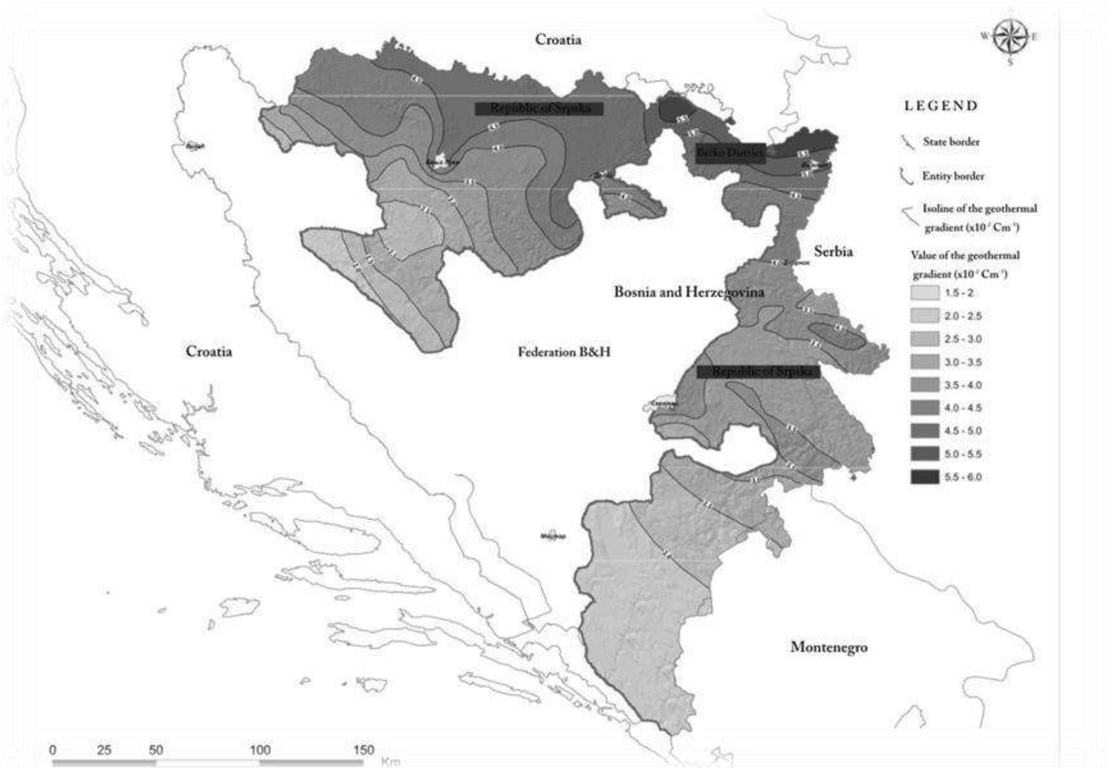

Figure 1. Spatial distribution of geothermal gradient in the territory of the Republic of Srpska

In the teritory of the Republic of Srpska its values range from 10°C/km (karst terrains of Eastern Herzegovina) up to maximal 55°C/km (Semberija).The map indicates favourable distribution of the parameter, because the highest values correspond tothe most populated and the most developed areas (Banja Luka, Bijeljina etc.).

3. Possibilities of geothermal energy use in different purposes

TheLindal diagram is broadly accepted as the best proposed diagram of geothermal energy use with different fluid temperatures,(Figure 2, after B. Lindal, an Island engineer who first proposed scale with appropriate temperatures for different use, 1985).

The division of geothermal resources in accordance with temperature is usually the following: low (<90°C), moderate (90-150°C) and high temperature fluids (>150°C).

High temperature fluids are mostly used for electricity production, moderate and low temperature fluids for direct use.

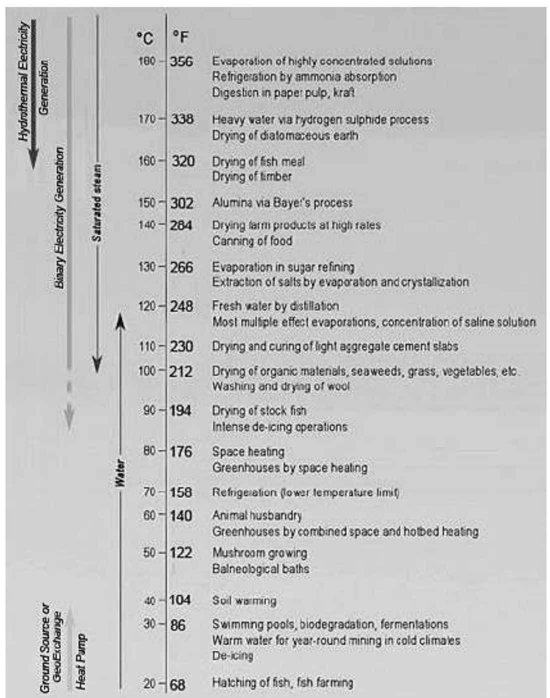

Figure 2. Lindal diagram

The most important types of direct use are:

-space heating and cooling

-heat pumps (increase temperatures of low temperature fluids)

-green house production of vegetable and fruit

-swimming pools and balneology

-industrial use and drying processes

-aquaculture (heating for fish farming)

The most frequent use of geothermal energy is the convective heat transfer by fluids (usually hot water or a mixture of hot water and steam), with different admixtures (gases, salts, minerals etc).
In addition, more detail review of possible uses of geothermal energy is shown.

Electricity production

Geothermal fluid-hot water or steam, with the temperature more than 120°C, latent heat converts into mechanical work, respectively electricity.

A few processes for conversion of heat to electricity are possible to apply, depend on thermodynamic properties of geothermal fluid. The selection of a process depends on fluid recharge, pressure and temperature, the ratio of hot water and steam, the content of non-condensate gasses, the conditions of scale precipitation and the conditions of corrosion occurrence.

Simple process**:** Electricity production from dry steam is the most simple and the most economic process. Under pressure, steam from a geothermal source is directly brought on turbine paddles. After the short adiabatic expansion, under atmosphere pressure of 1 bar, instead condensate pressure of 0.04 bar, the steam is pushed in the air.

Clausius-Rankine process: A mixture of water, steam and large particles has been brought from a production borehole toa centrifugal separator (with a cluster of thin sheet metals for drying and steam separation). Dry satiate steam produced in that way reaches a steam turbine, together with accompanied gases (in the first order carbon dioxide and sulphur dioxide). The same water, already passed through working process, is usedfor cooling of the capacitor, of course after it firstly passes througha cooling tower. Accompanied gases, with two-step compression, are the first in intermediate level upraised to atmospheric pressure, after that push in the air.

*Flash process***:** Residual water from the separator can be, under lower pressure, partly converted to steam again, thereby so-called "flash-separators". This additional steam had brought in the middle turbine level. The process is further carried out like in the Clausius-Rankine process.

*Binary process***:** Binary process is applied for moderation of temperature geothermal sources, which contain a huge amount of unfavourable accompanied gasses. During the process, geothermal fluid in a heat exchanger gives off the heat to the secondary, easy volatile fluid. The fluid moves turbine paddles. Furthermore, geothermal fluid is back in the aquifer by an injection borehole (Figure 3).

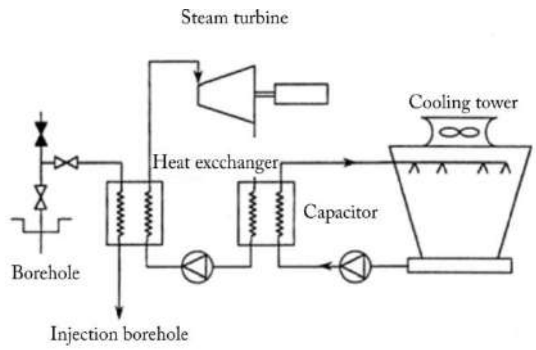

Figure 3. Scheme of binary process

Stirling process: Binary process use helium as working fluid and also can work in the Stirling process (especially after Japanese success in applying of low-temperature engine).

Direct use of geothermal energy

Geothermal water, or precisely its heat, is used mostly directly. It means it is used without any transformation to some other type of the energy. In smaller degree it is used for electricity production. Direct use of geothermal energy replaces other energy sources which pollute air and whole environment. The most usual ways of direct use are the following:

1. *Space heating* – geothermal energy is used directly or in heat exchanger (dependant on fluid purity) and brought to a heat consumer. Heat pumps and boilers with classic fuels are usedfor additional heating. The most usual direct use is for individual or district heating.

Within this kind of system, hot water from a borehole, via pump, is brought directly into a heating system or a heat exchanger.In indirect system of heating hot water, in a heat exchanger, surrender their heat to other heat circuit, with some other fluid or fresh water. After heat transmission, thermal water is directed from the heat exchanger to the injection borehole in the aquifer, again.
Direct use of geothermal energy for heating, industrial processes or for some other purposes always means the system consists from three components:
-production borehole –to provide thermal water on the surface
-mechanical system – includes pumps, heat exchangers and elements for control, use to introduce the heat in the space
-injection borehole - to provide cooled water back into aquifer
2. Agriculture – in agriculture, this kind of renewable energy source is used for different methods of green house heating (for radiator heating of soil, radiator heating of soil and air, heating of soil and/or air with blowing etc.), directly or by heat exchangers for space heating.

Thermal water with lower temperature and mineralization can be successfully used for irrigation and/or heating of cultivated areas.

Geothermal energy used in green houses can decrease total production costs up to 35% of.

3. *Balneology*– In some countries this kind of geothermal energy use is in praxis thousands of years for healing in spa, for recreation-medicinally bathing. Medicinally effects of thermal springs were good recognised in the history worldwide. It is well-known that thermal waters contain abundance of different minerals and chemical elements with very positive effects on human health, especially on skin diseases.

4. *Industrial use* – geothermal energy can be used in different industrial heat processes as pasteurization, drying, dehydration etc.

5. *Fish farming* – mostly for production of fish fry, temperature of water can improve fish rate production.

Further, geothermal energy can be use for paper production, milk pasteurisation, swimming pools, in processes of wood and wool drying and in many other purposes.

Heat pumps

The use of geothermal energy by heat pumps is a characteristic type of direct use. Geothermal heat pumps (or just GHP) have wide application in many European countries and in the USA. Heat pumps consume electricity for geothermal fluid circulation (open loop) or some other secondary fluid which takes the heat from soil (closed loop) through pipes (Figure 4)

.

.

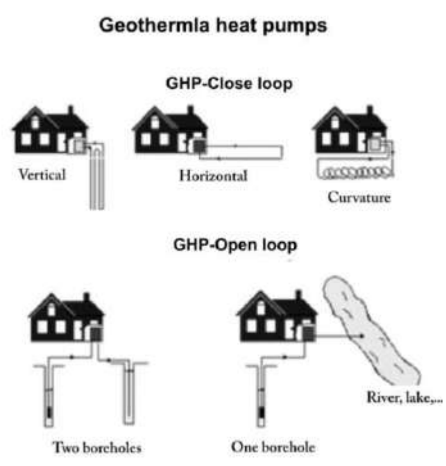

Figure 4. Geothermal heat pumps

In that way geothermal heat is brought to households. It is mostly use for space heating, in smaller degree for cooling and water heating.

This kind of application of geothermal energy significantly decreases electricity consumption. There are systems with buried heat exchangers which take heat from the Earth crust or systems take heat from geothermal fluid from boreholes, so-called borehole heat exchangers. Groundwater is brought to a heat exchanger from the borehole. In the exchanger a part of groundwater heat is transmitted to Freon, and it evaporates. Partly cooled water is brought up to other boreholes – injection boreholes and back to the aquifer. Freon, now in gas physical state, is compressed and releases the transmitted latent heat and transfers the heat to water circulated in the system of pipes.

4. Geothermal characteristics of the Republic of Srpska

Geothermal characteristics of the territory of the Republic of Srpska are closely related to its geological setting and tectonic characteristics. The way of the manifestation of geothermal phenomena, in the first order hydrothermal phenomena, are strongly dependent on various geological, geomorphological, geophysical, paleo and neo-tectonic characteristics.

The territory of the Republic of Srpska is characterised by very complex geological and tectonic settings. It is the reason why geothermal characteristics are different from area to area.

The biggest part of the territory of the Republic of Srpska belongs to the Dinaric orogeny, just a smaller part (at the north-east) belongs to overall southern edge of the Pannonian basin. Within these two units the rocks of the Lower Paleozoic to the Neogene and the Quaternary age were determined.

The basic type of geothermal potential is hydrothermal potential. Beside this one, over-pressed (geo-pressed) and petro-geothermal systems, in accordance with geological setting, are assumed.

Only hydrothermal systems are in exploitation today. It is the reason why these kinds of the systems are in the focus of this paper.

Other two types would be interested in the future, strongly dependent on development of appropriate exploration and exploitation technologies.

Exceptholokarst terrains of the Eastern Herzegovina, the rest of the territory is characterised by smaller or bigger geothermal potentiality. The most important proven hydrothermal systems are located in the north of the territory, within so-called “the area of wide artesian basins” (in the first order the territories of Semebrija and Posavina). The second important area, with numerous surface manifestation of geothermal activity (hot springs), is the zone of ophiolite belt, stretched from the overall east (Višegrad), via Zvornik, Teslić, Banja Luka to the overall west (Novi Grad) of the Republic of Srpska.

Key results on potentiality of the artesian basins were obtained in Semberija, in 1956, during drilling of the borehole S-1. This borehole is still in use in Dvorovispa. This positive result was confirmed further by drilling of the boreholes B-1 (1984), DV-1 (1989) and GD-2 (2010).

In the Posavina region the most important results were obtained from the borehole in Domaljevac village (the territory of the Federation of Bosnia and Herzegovina, distanced about 5 km from the entity border). Maximal registered artesian discharge of the borehole D-1 was 20 l/s with water temperature about 92°C.

During the later oil and gas explorations of the territory of the Republic of Srpska (80s of the last century) in the area of Obudovac and Brvnik, in significantly more depths than one in Domaljevac, the Triassic limestones were not reached (this limestone represents athermal reservoir in Domaljevac).

Other important occurrences of thermal water in the territory of the Republic of Srpska belong to the ophiolite zone.

Only two locations with water temperature more than 20°C are registered in the eastern part of the RS: the first one very close to Višegrad town (Vilinavlas) and the second one in the canyon of the Drinjačariver (two sites, Perin grad and Raševo). Other occurrences of thermal waters in the ophiolite zone are registered mostly along so-called “Spreča fault” (Sočkovac, Teslić, Kulaši, Slatina, Lješljani), in the western part of Srpska.

It is necessary to emphasise that within geothermal explorations in the RSin the past, mostly so-called „transient“ aquifers were determined (zones of ascending flow of thermal water from primary aquifers thru fault zones up to surface) and in a smaller degree primary aquifers (e.g. in Semberija were drilled the Triassic limestones on depths more than 1500 m represents rocks in which thermal water has stored). Determination of the primary aquifers in Banja Luka region (ophiolite zone) will be one of the main tasks in the future.

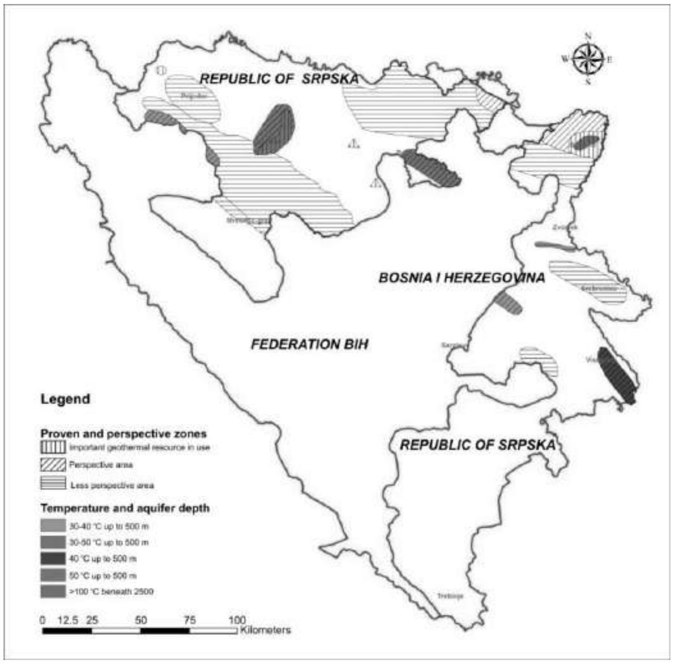

Figure 5. Proven and perspective area regarding geothermal energy in the Republic of Srpska

Within the zone of intermediary volcanites (wider area of Srebrenica) just mineral waters are registered up to date. Taking into account the Tertiary age of volcanites, there are some small possibilitiesto determine high enthalpy fluids in the deeper zones [6].

Also, some other kind of geothermal systems can be interesting for exploration in the future (e.g. geopressured geothermal systems)[6].

Based on the current level of geothermal knowledge in the territory of the Republic of Srpska the map of proven and perspective geothermal zones has created (Figure 5).

5. State of geothermal energy use in the Republic of Srpska

Modern technology provides possibility to use geothermal energy everywhere, dependant on the geothermal energy manifestation – in direct way or by heat pumps.

The use of geothermal energy in Europe is different, from country to country, and in the close relation with geothermal technology. Spectra of use include electricity production from high enthalpy systems (Island, Italy, Greece, Turkey), direct use of hydrothermal resources in sedimentary basins (France, Germany, Poland, Italy, Hungary, Romaniaetc).

Sub-geothermal systems are practically available everywhere and their usesare possible by heat pumps.

Electricity production in Europe, from geothermal sources, currently reaches 1850 $MW_{el}$of install capacities[1].

Despite the fact that the territory of the Republic of Srpska has favourable geothermal properties, utilization of this kind of renewable energy resourceis inadequate (in the whole territory of Bosnia and Herzegovina as well) (Figures 6 and 7).

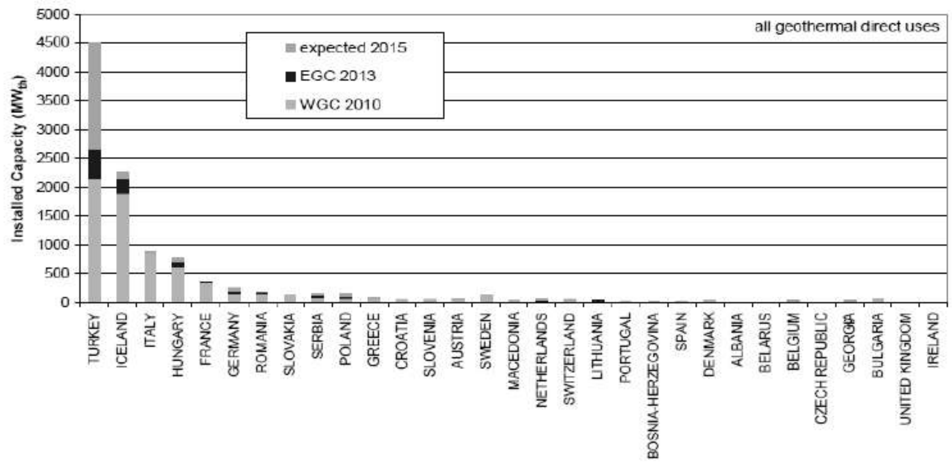

Figure 6. Direct use, installed capacities in Europe (EGEC, Keynote, Summary of EGC 2013 Country Update Reports on Geothermal Energy in Europe)

Even more indicative data are the data about geothermal energy use by heat pumps (of course, in the bad sense).

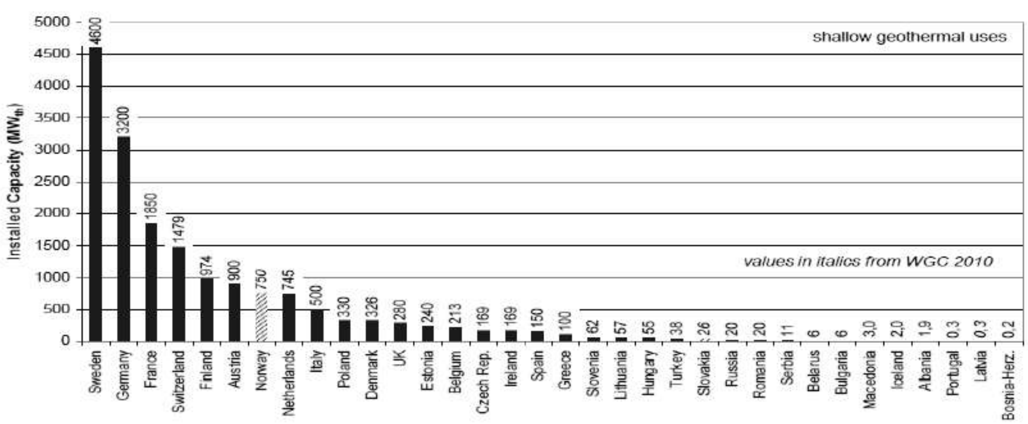

Figure 7. Heat pumps, installed capacities in Europe (EGEC, Keynote, Summary of EGC 2013 Country Update Reports on Geothermal Energy in Europe)

The review of possible production of energy from geothermal sources in some locations in the territory of the Republic of Srpska is given in the following figure.

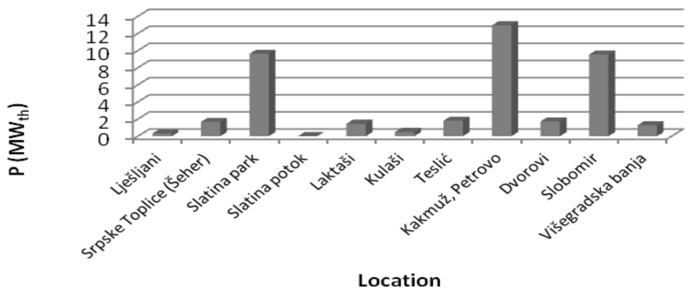

Figure 8. Current possibilities of geothermal energy production in some localities in the territory of the Republic of Srpska

Additional 2.5-3.0 MW_{th} can be captured from the thermal springs (accepted referent temperature for calculation was 20°C). The structure of the hydrothermal energy use is more than inappropriate and mostly reduced on traditional use – for balneology and recreation (very rarely for space heating exclusively in spa's buildings).

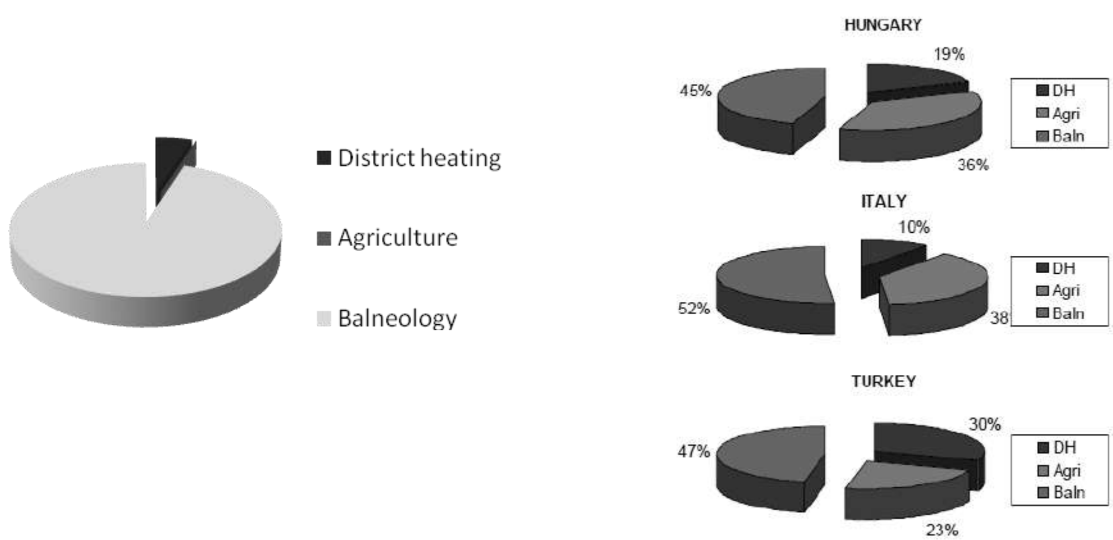

Figure 9. Share of district heating, agriculture uses and balneology in geothermal direct use in the Republic of Srpska and some more developed countries for 2012

6. Chemical composition of thermal water and its importance for exploration and exploitation

Chemical composition of thermal waters plays very important role for their: exploration, analyses of possibility of use and also for prediction of exploitation effects.
This chapter is divided into three subchapters:

a. Chemical composition of thermal waters in the territory of the Republic of Srpska

b. Use of thermal waters chemical composition for prediction of temperatures of fluid

c. Parameters of chemical composition in sense of suitability of thermal waters for its exploitation

7.1. Chemical composition of thermal waters of the Republic of Srpska

The chemical composition of thermal waters in the Republic of Srpskais briefly reviewed from the following figure and the table. All occurrences of these waters are located north from the line Foča-Mrkonjić Grad-Novi Grad.
There are different hydro-chemical types of thermal waters, but in macro-component sense generally prevail theanion HCO_3 (just in LješljaniCl) and the cationsCa and Na.
A short review of hydro-chemical types of the thermal waters is given in the following table (in accordance with *Kurlov* classification).

Table 1. Hydrochemical types of thermal waters in the territory of the Republic of Srpska

No	Location	Hydro-chemical type
1.	Laktaši	HCO_3-Ca-Mg
2.	Šeher	HCO_3-SO_3-Ca-Mg
3.	Slatina	HCO_3-SO_3-Ca-Mg
4.	Teslić	HCO_3-Cl-Ca-Na
5.	Sočkovac	HCO_3-Ca-Mg
6.	Dvorovi	HCO_3-Cl-Na
7.	Kulaši	HCO_3-Ca
8.	Višegrad	HCO_3-Ca-Na
9.	Lješljani	Cl-HCO_3-Na

Total mineralisation of thermal waters is mostly up to 2500 mg/l. Thermal water in Kulašihas the lowest mineralisation (about 300 mg/l), and waters in Slatina and Sočkovac has the biggest one (about 3500 mg/l). The pH value is generally up to 8, except thermal water in Lješljani with very high pH value - more than 11.5.

Various micro-components (do not impact on water type, but impact on water specificity) occurs: Br and J (e.g. in Teslić, in small concentration, J also occurs in small concentration in Dvorovima), F (in Dvorovi, as well), Sr (Višegrad, Slatina), B (Slatina) etc.
Gas composition of the thermal waters in Srpska testifies about their atmospheric origination.

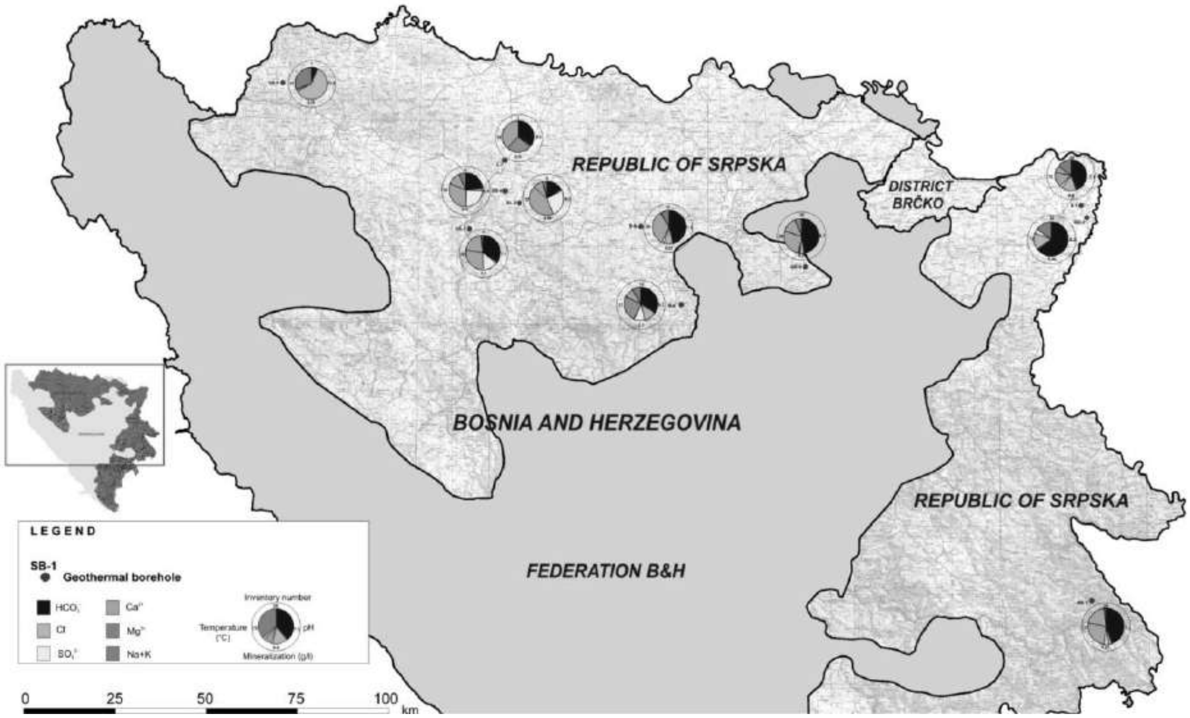

Figure 10. Hydrochemical map of thermal waters in the Republic of Srpska

7.2. Geothermometers - use of parameters of chemical composition for prognosis of temperature of fluid in the aquifer, the example of Banjaluka region

Chemical and isotope composition of thermal water has big importance for its exploration.During an exploration, some elements (so-called geo-thermometers), determined by thermal springs laboratory analyses, can be very useful for estimation of fluid subsurface temperature. Chemical composition of thermal water, exploited by well, drilled in fracture zones (zones of ascending flow of the thermal waters), can be used for prognosis of the fluid temperature in the primary aquifer, as well. It is well-known that the temperature of ascending flow of thermal water, from deep reservoirs to the surface, can be reduced by conductive heat loss (caused by contact with cooler rocks).

The application of some geo-thermometers is different, from reservoir to reservoir. Some geo-thermometers, because of inappropriate application, provide misleading results (over or underestimated fluid temperature value). Applicability of some geo-thermometers must be recognized from the researcher.

In addition, the example of estimation of the thermal water temperature in primary aquifer,is given for three locations,within Banja Luka region (Table 2), were thermal waters captured by wells in fracture zones which intersect impermeable cap rocks of the aquifer. Furthermore, some calculations are made based on the results of the chemical analyses of the thermal springs.

Three types of geo-thermometers were used for estimation of subsurface fluid temperature: SiO_2, Na-K and Na-K-Ca.

The following equations were used for the calculations[4]:

- for SiO_2 (Fournier, 1977)

$$t(^{\circ}C) = \frac{1309}{5.19 - \log(SiO_2)} - 273.15$$

- for Na-K (Fournier, 1979)

$$t(^{\circ}C) = \frac{1217}{1.438 - \log(\frac{Na}{K})} - 273.15$$

- for Na-K-Ca (Fournier and Truesdell, 1973)

$$t(^{\circ}C) = \frac{1647}{\log(\frac{Na}{K}) + b\log(\frac{\sqrt{Ca}}{Na}) + 2.24} - 273.15$$

were,

b=4/3 for $Ca^{1/2}/Na > 1$ and $t < 100°C$ or
b=1/3 for $Ca^{1/2}/Na < 1$ or if $t_{4/3} > 100°C$

Table 2. Estimation of thermal waters temperature in primary aquifer for Šeher, Laktaši and Slatina

SiO_2 geo-thermometer				
Well or spring	Locality	SiO_2 (mg/l)		T (^{O}C)
GŠ-1	Šeher	25.00		72.09
Šaranovićahaus	Šeher	24.00		70.48
Gušićahaus	Šeher	26.00		73.65
L-1	Laktaši	5.86		22.90
L-3	Laktaši	5.85		22.85
Glavnizvor	Laktaši	13.23		48.63
Glavnizvor	Laktaši	16.00		55.30
SL-1	Slatina	33.00		83.43
SL-2	Slatina	16.50		56.41
SL-3	Slatina	20.00		63.49
KB-1	Slatina	34.60		85.44
Na-K geo-thermometer				
Well or spring	Locality	Na (mg/l)	K (mg/l)	T (^{O}C)
GŠ-1	Šeher	29.40	1.20	150.57
Šaranovićahaus	Šeher	36.30	12.00	346.59
Gušićahaus	Šeher	36.00	13.00	358.94
L-1	Laktaši	10.10	1.30	239.62
L-3	Laktaši	12.56	1.13	208.08
L-3	Laktaši	13.30	1.38	220.17
Glavnizvor	Laktaši	20.15	1.64	199.94
SL-1	Slatina	127.5	43.00	349.34
SL-2	Slatina	100.00	28.00	324.64
SL-3	Slatina	81.00	26.30	344.14
KB-1	Slatina	129.1	34.55	318.93
Na-K-Ca geo-thermometer				

Bušotina	Lokalitet	Na (mg/l)	K (mg/l)	Ca (mg/l)	T (°C)
GŠ-1	Šeher	29.40	1.20	160	99.63
Šaranovićahaus	Šeher	36.30	12.00	180	199.05
Gušićahaus	Šeher	36.00	13.00	174	204.48
L-1	Laktaši	10.70	1.30	110.8	132.22
L-3	Laktaši	13.30	1.38	122.4	127.83
SL-1	Slatina	127.50	43.00	480	215.65
SL-2	Slatina	100.00	28.00	366	202.09
SL-3	Slatina	81.00	26.30	400	205.92
KB-1	Slatina	129.10	34.55	415.1	203.18

From the table it is obvious that the values calculated for Na-K and Na-K-Cageothermometer are not realistic or, in the other words, these values are seriously overestimated. It indicatesinapplicability of these two methods in specific case.

From the other side, values calculated in accordance with SiO_2equation are much more realistic, exceptthe results obtained for the wells L-1 and L-2 in Laktaši.

Calculation of the water temperature in a primary aquifer e.g. in Slatina, in accordance with the equation for SiO_2 geo-thermometer, gives the temperature of 70-80°C. Taking into account value of geothermal gradient for this area (about 42°C/km) it means that the aquifer (probably created in the Triassic limestones) is on the depth 1500-1700 m beneath the surface. Applicability of this method for thesethermal waters is supported by results of geophysical explorations [8] which indicate very similar depth of thermal aquifer.

7.3. Thermal water quality parameters use for estimation of its exploitation suitability

It is a fact that thermal water isthe most frequently exploited by vertical drilled wells. Like each other objects, a well has its work period (optimal period of exploitation). A period of exploitation depends on different criteria: chemical composition of thermal waters, technical characteristics of wells e.g. screen material, construction and exploitation regime etc.

Decline of well yield during its exploitation is the result of two processes: corrosion and incrustation.

Corossion is a phenomenon linked exclusively to well screen and represents its physical degradation. There are several types of the process of corossion and it is a particular problem of styding.

Incrustation is a process of salts and insoluble particles precipitation. The process occurs on well screen, but also in the zone close to well. Ther are two colmatation types: chemical and biological.

In the aim of estimation of potentiality of iron hydrocarbon separation and precipitation of $CaCO_3$ from water, stability of groundwater, from chemical point of view in natural condition, is necessary to define.

Based on the results of chemical analyses it is possible to calculate pH_s value – index of hydrogen ions which corresponds to equilibrium saturation of groundwater with carbonic acid compounds.

It is calculated under the following equation [2]:

$$pH_s = 9{,}92 - \frac{t[^\circ C]}{40} - \log\left[Ca^{2+}(mg/l)\right] - \log\left[HCO_3^-(mg/ekv/l)\right] + 0{,}2\log\left[S.O.(mg/l)\right]$$

where:

S.O. - total dry residue (mg/l),

t - temperature of groundwater in natural condition in aquifer (°C),

Ca^{2+} - ion of calcium which can be determined in the field of calculate as CaO as follow:

$$Ca^{2+}(mg/l) = \frac{CaO(mg/l)}{1{,}4}$$

HCO_3- hydrocarbonwhich can be determined in the field (mg/ekv/l) or calculate as:

$$HCO_3^- (mg/ekv/l) = \frac{HCO_3^-(mg/l)}{61}$$

After calculation of pH_svalue, indexof saturation I, under O.Langelier is:

$$I = pH - pH_s$$

The value of I indicates two cases. The first one when I>0 means that content of CO_2 in water is under the equilibrium concentration and precipitation of carbonate happens and the second one when I<0 means that CO_2 is above the equilibrium concentration and water is able to solve carbonates. Based on the results of a large number of experiments and explorations of waters of different chemical composition, Ryznar introduced criteria of stability index (Ryznar number)

$$R = 2pH_s - pH$$

Based on the index of saturation and the index of stability, taking into account the content of some most frequent water components like ($Fe(OH)_3$, SiO_2, Al_2O_3 etc.), the classification of groundwater is givenin five groups:

First type: includes water with R>9, I≤0, SiO_2<10 mg/l in which prevail processes cause screen material corrosion. This type of water causes rapid deterioration ofskeletal screens with sieves and screens with vertical slots.

Second type includes water with Fe^{3+}>0.3 mg/l, R<9, I>1, with intensive incrustation of ($Fe(OH)_3$) on gravel fill and sieve and screen holes. In this case, skeletal screens are highly recommendable with sieve and gravel fill as well as frequent regeneration (each 1.5-2 years).

Third type includes water with R<9, I≥0, Fe^{3+}<0.3 mg/l, SiO_2<10 mg/l, which are prone to precipitation of $CaCO_3$ and $MgCO_3$ on gravel fill, sieve and screen.

Fourth type includes water with SiO_2 or Al_2O_3>10 mg/l with precipitation of silica salts and aluminum-silicates, and partly iron hydroxide, with same, negative, impact on each kind of the screen. Removal of aluminum oxide and others is provided by regeneration process with flour-hydrogen acid with inhibitor from acetic acid.

Fifth type includes water with Fe^{2+} concentration more than 0.3 mg/l, pH<7,2 and M<1 g/l whichimprove iron bacteria growth in the zone close to screen, gravel fill and screen (biological incrustation). All types of screen are equally exposed to biological incrustation. It is minimized by installing of a thick layer of gravel fill. Biological incrustation removes by HCl and some other strong oxidation compounds.

Table3. Calculated values of Langelier number, index of saturation and Risnar number for some thermomineral waters in the Republic of Srpska

Param-eter	Dvor-ovi	Gornji Šeher	Kulaši	Lješljani	Slatina	Slobomir	Sočkovac	Teslić	Višegrad
pHs	6.34	6.57	7.55	8.05	5.61	6.80	5.39	5.55	7.22
I	0.76	0.56	-0.05	3.80	0.76	0.70	1.21	0.75	0.08
R	5.57	6.02	7.60	4.25	4.85	6.10	4.17	4.80	7.15

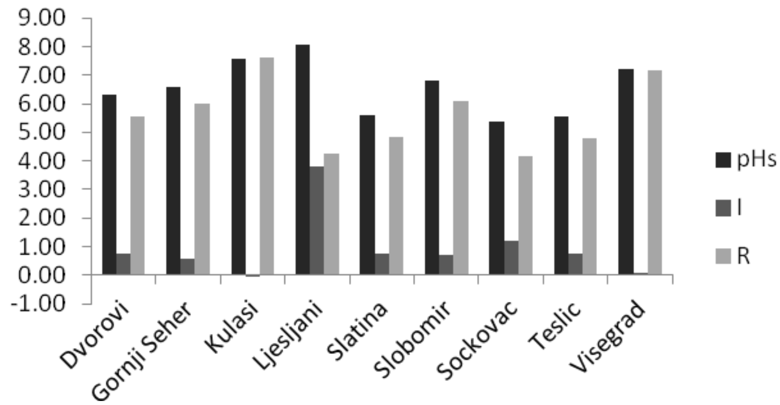

Figure11. Langelier number, index of saturation and Ryznar number of thermal and thermomineral water in the Republic of Srpska

In the aim of selection of the most suitable well construction (especially well screen), to secure dependant long-term thermal water exploitation, calculated numbers must be taken into account together with components like SiO_2, Fe^{3+}, $Fe(OH)_3$, Al_2O_3 etc.

CONCLUSION

Geothermal energy represents the heat originated by natural processes happen in the Earth interior. Hot springs are natural phenomena created by geothermal activity. This kind of springs we find in many areas worldwide, in the Republic of Srpska as well. Geothermal energy is highly ecologically acceptable.

Key elements for origin of a geothermal system are: 1) heat source; 2) reservoir for heat accumulation and 3) presence of roof barriers which conditional storage of heat in reservoir.

Geothermal gradient is a basic parameter for estimation of geothermal potentiality of an area. Taking into account the map of distribution of this geothermal parameter in the territory of the Republic of Srpska (Jolović et al., 2012) it is possible to conclude about higher geothermal potentiality of northern parts of the Republic of Srpska, in the first order Semberija, Posavina and Banja Luka regions. In the territory of the Republic of Srpska its values range from 1°C/km (karst terrains of Eastern Herzegovina) up to maximal 55°C/km (Semberija). The map indicates favourable distribution of the parameter, because the highest values correspond with the most populated and the most developed areas (Banja Luka, Bijeljina etc.).

The way of geothermal energy use depends on its temperature. High temperature fluids are mostly uses for electricity production (not registered in RS), moderate and low temperature fluids (registered in RS) for direct use: space heating and cooling, heat pumps, green houses, swimming pools and balneology, industry and aquaculture.

The biggest part of the territory of the Republic of Srpska belongs to the Dinaric orogeny and just a smaller part (at the north-east) belongs to the overall southern part of the Pannonian basin, well-known as European geothermal anomaly.

The most important proved hydrothermal systems are located in the north of the territory, within so-called "area of wide artesian basins" (without surface manifestation of geothermal activity), in the first order territories of Semebrija and Posavina. The second important area, with numerous surface manifestation of geothermal activity, is the zone of ophiolite belt, stretched from the overall east (Višegrad), via Zvornik, Teslić, Banja Luka to the overall west (Novi Grad) of the Republic of Srpska.

Only two locations with thermal springs (T>20ºC) are registered in the eastern part of Srpska (near Višegrad and in the Drinjača river canyon near Milići). Other thermal spring are registered mostly along so-called Spreča fault zone (Sočkovac, Teslić, Kulaši, Slatina, Lješljani) in the western part of Srpska.

These two areas (wide artesian basin and ophiolite zone) are the most important from the aspect of further geothermal explorations.

Despite the fact that territory of the Republic of Srpska has favourable geothermal properties, utilization of this kind of renewable energy resource is inadequate.Also, the structure of hydrothermal energy use is more than inappropriate and mostly reduced on traditional use – for balneology and recreation (very rarely for space heating exclusively in spa's buildings). It entails as soon as possible adequate improvement. In the future, heat pumps must play more important role in geothermal use as well.

Chemical composition of thermal water playsvery important role in its exploration and exploitation. Some elements, named geothermometers, are used for prognosis of fluid temperature in the aquifer. Further, in the aim of selection of the most suitable well construction (especially well screen), to secure dependant long-term thermal water exploitation, Langelier number and Ryznar index must be taken into account together with components like SiO_2, Fe^{3+}, $Fe(OH)_3$, Al_2O_3 etc.

REFERENCES

[1] Antics, M., Bertrani, R., Sanner, B Summary of EGS 2013 country update Reports on geothermal energy in Europe, EGC, 2013, 3-5

[2] Vuković, M. Hydraulic of wells, Institute Jaroslav Černi, Beograd, 1995, pp 227-231

[3] Gupta, H. Geothermal Energy: An Alternative Resource for the 21st Century, APA, 2007, pp 49-59

[4] Karingithi, C. Chemical geothermometers for geothermal explorations,Short Course IV on Exploration for Geothermal Resources, UNU-GTP, 2009, 4-7

[5] Jolović, B. Et al. Geothermal Atlas of the Republic of Srpska, Geozavod, Zvornik, 2012, pp

[6] Miošić, N. Geothermal energy of Bosnia and Herzegovina, Geoinženjering, Sarajevo, 1987, pp 91

[7] Pruess, K. Lecture 1, Hydrothermal systems, Geothermal training programme, United Nations University, Reykjavik, 2002, 1-2

Romantić, S. Geophysical explorations of Banja Luka region, Geofizika, Zagreb,1983, 8-9