AACL BIOFLUX
Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

The Romanian perspective on geothermal energy resources. The chemistry of the geothermal waters from Oradea Triassic aquifer

[1]Ruxandra M. Petrescu-Mag, [1]Carmen Roba, and [2]D. Crina Petrescu

[1]Babes-Bolyai University, Faculty of Environmental Science, Cluj-Napoca, Romania;
[2]Babes-Bolyai University, Faculty of Business, Cluj-Napoca, Romania.
Corresponding author: R. M. Petrescu-Mag, pmalina2000@yahoo.com

Abstract. In 2008, the European Commission put forward a proposal for a new directive (COM (2008) 30) on renewable energies to replace the existing measures adopted in 2001. According to the proposal, each member state should increase its share of renewable energies - such as solar, wind or hydro - in an effort to boost the EU's share from 8.5% today to 20% by 2020. According to Cohuţ & Bendea (2000) in Romania are over 200 wells drilled to depths between 800 and 3500 m that encountered geothermal resources at temperatures from 40 to 120 °C. These wells have a total thermal capacity of about 480 Mwt. The Oradea aquifer was identified between 1963-1964 by the drills 4005 and 4006. To establish the content of the major elements of the geothermal waters from the production wells from Oradea, the geothermal fluids were sampled and analyzed during six months (since October 2007 to March 2008), by using ion chromatographic (IC) method. In this period of the year, the geothermal installations are used at the maximum capacity.
Key Words: geothermal energy, renewable energy, chemistry, Oradea aquifer.

Resumen. En 2008, la Comisión Europea ha adoptado una propuesta para una nueva directiva (COM (2008) 30) sobre energía renovables que remplazara el marco legislativo actual adoptado en 2001. Conforme a la propuesta, cada estado miembro será impulsionado para aumentar la cantidad de energía de origen renovable ya que su porcentaje crezca en la UE del 8,5% en la actualidad al 20% hasta 2020. Según Cohut & Bendea (2000) en Rumanía hay mas de 200 sondas géotermicas con profundidad entre 800 y 3400 m, con temperaturas entre 40 y 120 °C; la capacidad termal llega hasta 480 MWt. El acuífero de Oradea fue identificado en los años 1963-1963 a través de las sondas 4005 y 4006. Para la evaluación de la composición química de las aguas geotermales se han hecho una serie de análisis químicos para diferentes sondas. La toma y la analización de las muestras se han hecho en los meses del estación frió (octubre de 2007 - marzo de 2008), en esta temporada las instalaciones géotermicas funcionan a sus capacidad máxima. Se han respetado los estándares para estos procidiminetos. Los datos químicos se han conseguido utilizando la cromatografía de íons (CI).
Key Words: energia géotermica, energía renovables, quimismo, acuífero de Oradea.

Rezumat. În 2008, Comisia Europeană a înaintat o propunere de directivă (COM (2008) 30) privind energia din surse regenerabile, care ar trebui să înlocuiască reglementările adoptate în 2001. Potrivit propunerii, fiecare stat membru trebuie să crească cantitatea de energia produsă din surse regenerabile, astfel încît ponderea acestora în UE să crească de la 8,5% în prezent la 20% până în 2010. După Cohut & Bendea (2000) în România există peste 200 de sonde forate pentru ape geotermale cu adâncimi cuprinse între 800 şi 3400m, temperaturile variind între 40 şi 120 °C; capacitatea termală a acestora fiind în jur de 480 MWt. Zăcământul geotermal Oradea a fost identificat în anii 1963-1964 prin sondele 4005 şi 4006. Pentru evaluarea compoziţiei chimice a apelor geotermale au fost efectuate o serie de analize chimice pentru diferite sonde apartinând perimetrului studiat. Prelevarea şi analiza probelor s-au efectuate în lunile anotimpului rece (octombrie 2007 - martie 2008), perioadă în care instalaţiile geotermale funcţioneză la capacitatea maximă, respectându-se standardele valabile în prezent pentru aceste proceduri. Datele chimice au fost obţinute prin intermediul metodei de analiză ion cromatografică (IC).
Cuvinte cheie: energie geotermală, energie regenerabilă, chimism, acviferul de la Oradea.

Introduction. Geothermal energy is a renewable energy source because the water is replenished by rainfall and the heat is continuously produced inside the Earth. Geothermal resources range from shallow ground to hot water and rock several miles below the Earth's surface, and even farther down to the extremely hot molten rock called magma (Bobin et al 2005). Mile-or-more-deep wells can be drilled into underground reservoirs to tap steam and very hot water that can be brought to the surface for use in a variety of applications. There are three primary applications of geothermal energy: electricity generation, direct use of heat, and ground-source heat pumps. Utility-scale geothermal power production employs three main technologies. These are known as dry steam, flash steam and binary cycle systems. The technology employed depends on the temperature and pressure of the geothermal reservoir. Unlike solar, wind, and hydro-based renewable power, geothermal power plant operation is independent of fluctuations in daily and seasonal weather. As of 2000, approximately 8000 megawatts (MW) of geothermal electrical generating capacity was present in more than 20 countries, led by the United States, Philippines, Italy, Mexico, and Indonesia (International Geothermal Association 2003). This represents 0.25% of worldwide installed electrical generation capacity. In the United States, geothermal power capacity was 2228 MW, or approximately 10% of non-hydro renewable generating capacity in 2001 *(*Energy Information Administration 2001)*.* This capacity would meet the electricity needs of approximately 1.7 million U.S. households.

Geothermal energy sources can be classified into three types:

- Low- and medium-enthalpy geothermal energy: with a geothermic gradient of medium value. In this case it could be obtained 80^{o}C at 2000 m depth. These temperatures are used for buildings and greenhouses heating, in aquaculture and for other industrial and agriculture uses
- High -enthalpy geothermal energy. This type of energy is the only one that allows electricity to be generated directly; it is found in volcanic or tectonically active zones. In this case, it could reach 300^{o}C at 1000 m depth.
- Hot and fractured rocks. If the feasibility of producing electricity from hot and fractured rocks (HFR) were to be demonstrated, many regions of the planet would turn into potentially productive energy reserves.

Environmental impact and economic importance. Geothermal power plants do have some environmental impacts. However, these impacts should be balanced against geothermal energy's advantages over conventional power sources when conducting assessments of power plant project environmental impacts. The primary impacts of geothermal plant construction and energy production are gaseous emissions, land use, noise (Table 1), and potential ground subsidence. Environmental problems also arise during plant operation. Geothermal fluids (steam or hot water) usually contain gases such as carbon dioxide (CO_2) (see Table 2), hydrogen sulphide (H_2S), ammonia (NH_3), methane (CH_4), and trace amounts of other gases, as well as dissolved chemicals whose concentrations usually increase with temperature. For example, sodium chloride (NaCl), boron (B), arsenic (As) and mercury (Hg) are a source of pollution if discharged into the environment. Some geothermal fluids, such as those utilised for district-heating in Iceland, are freshwaters, but this is very rare. The waste waters from geothermal plants also have a higher temperature than the environment and therefore constitute a potential thermal pollutant (Dickson & Fanelli 2004).

Table 1

Geothermal exploration and construction noise levels by operation

Operation	*Noise level (dBa)*
Air drilling	85–120
Mud drilling	80
Discharging wells after drilling (to remove drilling debris)	Up to 120
Well testing	70–110
Diesel engines (to operate compressors and provide electricity)	45–55
Heavy machinery (e.g., for earth moving during construction)	Up to 90

Source: International Energy Agency, http://www.iea.org/pubs/studies/files/benign/pubs/appedn3g.pdf

Table 2

Comparison of CO_2 emissions by power source

Power source	*CO_2 emissions (lb/kWh)*
Geothermal	0.20
Natural gas	1.321
Oil	1.969
Coal	2.095

Source: http://www.repp.org/geothermal/geothermal_brief_environmental_impacts.html

The noise associated with operating geothermal plants could be a problem where the plant in question generates electricity. During the production phase there is the higher pitched noise of steam travelling through pipelines and the occasional vent discharge. These are normally acceptable. At the power plant the main noise pollution comes from the cooling tower fans, the steam ejector, and the turbine 'hum' (Brown 2000). The noise generated in direct heat applications is usually negligible.

The economic importance of electrical geothermal power depends on the deposit type. Most renewables have very different cost structures from conventional energy generating technologies, with high up-front costs and low operating costs. This is true for geothermal energy, which has high exploration and drilling costs in additional to capital plant expenses. With additional technology development, these costs can be lowered, and geothermal energy can become more cost-competitive with other energy sources. Renewable energy can reduce dependence on fossil fuels, reduce harmful pollution from energy production and consumption, and reduce emissions of greenhouse gases.

Thermal waters are often used by European aquaculturists in tropical fish rearing and/or reproduction. At Oradea (Romania), such a tropical fish is the African catfish *Clarias gariepinus* (Burchell) or the interspecific hybrid of *Clarias gariepinus* x *Heterobranchus longifilis* (Valenciennes). Combining thermal water with tap water the temperature is regulated and the cost of water heating diminished. Nevertheless, some ornamental fish hatcheries could also use this cheap source of thermal energy.

European Union trends towards renewables promotion. According to the last Action Plan on Energy Efficiency, Europe wastes at least 20% of its energy due to inefficiency. Consequently, realising the saving potential has been considered so far the most effective way to improve security of energy supply, reduce carbon emissions, foster competitiveness and stimulate the development of a large leading-edge market for energy-efficient technologies and products. The European Commission affirms that the challenge of the European Energy Policy is to turn Europe into a highly energy efficient and low CO_2 energy economy, catalysing a New Industrial Revolution, accelerating the change to low carbon growth and, over a period of years, dramatically increasing the amount of local, low emission energy that we produce and use, and highlights that Renewable Energy Sources (RES) are the key to change (de Alegria Mancisidor et al 2009). The Renewable Energy Road Map (Com (2006) 848), part of the Strategic European Energy Review, sets out a long term vision for renewable energy sources in the EU. It proposes that the EU establish a mandatory (legally binding) target of 20% for renewable energy's share of energy consumption in the EU by 2020, explains why it is necessary, and lays down a pathway for mainstreaming renewables into EU energy policies and markets. It further proposes a new legislative framework for the promotion and the use of renewable energy in the European Union. In 1997, the European Union started working towards a target of a 12% share of renewable energy in gross inland consumption by 2010 representing a doubling of the contribution from renewable energies compared with 1997. Since then, renewable energies have increased their contribution by 55% in absolute energy terms. The 12% target for the contribution from renewables to overall EU energy consumption by 2010 is unlikely to be met. Based on current trends, the EU will not exceed 10% by 2010. This can only be considered a policy failure and a result of the inability or the unwillingness to back political declarations by political and economic incentives.

On 23 January 2008, the Commission put forward a proposal for a new directive (COM (2008) 30) on renewable energies to replace the existing measures adopted in 2001. According to the proposal, each member state should increase its share of renewable energies - such as solar, wind or hydro - in an effort to boost the EU's share from 8.5% today to 20% by 2020. A 10% increase in biofuels use in transport fuel consumption is included within the overall EU objective. To achieve the targets, every nation in the 27-member states is required to increase its share of renewables by 5.5% from 2005 levels, with the remaining increase calculated on the basis of per capita gross domestic product (GDP) (see Table 3 for Romania).

Table 3

The case of Romania on renewable energy share

Member State	*Share of renewables in 2005*	*Share required by 2020*
Romania	17.8%	24%

Source: COM (2008) 30, Annex I.

The Commission also proposes a series of interim targets, in order to ensure steady progress towards the 2020 targets.
- 25% average between 2011 and 2012;
- 35% average between 2013 and 2014;
- 45% average between 2015 and 2016;
- 65% average between 2017 and 2018.

EU countries are free to decide their preferred 'mix' of renewables in order to take account of their different potentials, but must present national action plans (NAPs) outlining their strategies to the Commission by 31 March 2010. The plans will need to be defined along three sectors: electricity, heating and cooling and transport.

The most significant geothermal sources from Romania. Warm water (to 80^{o}C) from deep (500-2000 m) wells in sedimentary basins is used in Hungary (1630 GWh/yr), Bulgaria (220 GWh/yr), Slovakia (502 GWh/yr), Romania (360 GWh/yr), Poland (206 GWh/yr) and the former Yugoslavia (1085 GWh/yr), mostly for swimming pools, greenhouses, and health spas. Medium-temperature geothermal aquifers exist beneath almost all of Hungary, so wells can usually be located wherever heat is needed: for bathing (45%), greenhouses (42%), industry (10%) and space heating (3%). Large amounts are also cooled for drinking. In south-west Hungary, where thermal aquifers are the deepest and hottest (to 140 ^{o}C), more than 80% of all greenhouses are heated by geothermal waters. In Poland and the Czech Republic, hot waters rich in mineral salts from crystalline rocks are used for bathing and as medicine. The famous Czech thermal spas of Carlsbad and Marienbad have been popular for more than 500 years (http://geothermal.marin.org/map/easteurope.html).

In Romania were identified mesothermal waters (with temperatures between 36-41^{o}C) and hyperthermal waters (with temperatures above 41^{o}C). The geothermal waters from Romania are used mostly for balneological purposes, for buildings and greenhouses heating, for domestic warm water supply etc (Zaharia 2004). Geological prospecting (Airinei 1987) showed the existence of 66 geothermal sources, with spreading in Pannonian Basin, Getic Basin, Moesic Platform.

According to Cohuț & Bendea (2000) in Romania are over 200 wells drilled to depths between 800 and 3500 m that encountered geothermal resources at temperatures from 40 to 120 ^{o}C. These wells have a total thermal capacity of about 480 MWt; 96 of the wells are in use (35 for balneology and bathing), producing water with temperatures between 45 and 115 ^{o}C (Lund & Freeston 2001). The main geothermal resources are located in the north-west of Romania, near Oradea (including Borş and the Western Plain), and accounting for the majority of the uses in Romania; geothermal resources were identified and in the Olt Valley and north of Bucharest The geothermal aquifer from the north of Romania`s capital (Otopeni) riches 77°C at the bottom of the well. The water is used as thermal agent in Otopeni village. The main direct uses of geothermal energy are space and district heating (35%), bathing (30%), greenhouse heating (23%), industrial process heat (7%), and farming and animal husbandry (2%). During the past five years 14 wells have been drilled. Today there are 38 geothermal localities that use the geothermal water extracted by the 96 existing wells. The total capacity is 152.4 MWt, with an annual energy use of 2870.7 TJ (Lund & Freeston 2001). It is considered that only 20.5 % of Romanian geothermal potential is used (so 79.5 % remains available). It is considered that only mesothermal and hyperthermal waters present economical interest; in the present phase interests in investments for geothermal waters capitalization are situated around 45% of their energetic potential (Zaharia 2004).

Over 100 years, around Oradea town, drillings were made and geothermal waters were exploited for therapeutical purposes. In the last 25 years, systematic activities of prospecting and evaluation of both geothermal and hydrocarbon deposits were initiated in this part of the country. Thus, it was found out that in the Western Plain (Câmpia de Vest), there are located important geothermal aquifers with various thermophysical capacities and proprieties. The thermal flux from the surface has values around 85 MW/m^2, higher than those from other regions. One of the most important geothermal aquifer form Romania is located in the Pannonian Basin in the sandy rocks of Lower Pontian age. This multilayer aquifer has a surface around 2500 km^2 along Romanian-Hungarian board, from Satu-Mare to Timişoara and Jimbolia (http://www.agir.ro/univers-ingineresc/energia_geotermala_1664.html).

The chemistry of the geothermal waters from Oradea Triassic aquifer. The Oradea aquifer was identified in 1963-1964 by the drills 4005 and 4006. Then, between 1965-1988, it was geological and hydrodynamical researched, using 12 wells (see Figure 1) (Haiduc et al 2008). The Oradea aquifer is located in Triassic limestone and dolomites, at depths of 2200-3400 m; the surface of the geothermal perimeter is about 113 km^2. The aquifer is exploited by 12 wells, from which 11 wells are used as production wells and one for the reinjection of the waste geothermal water. The Oradea aquifer has a natural recharging with the outflow in the perimeter of Felix and 1 Mai Spa.

The geothermal water from the Oradea Triassic aquifer has temperatures between 70-105°C, the values are decreasing from the West (105°C) to the Est (70°C). The medium temperature of the 11 production wells is around 90°C (Țenu 1981; Cohuț 1986). The energetic potential of the 12 wells is around 150000 Gcal/year and the annual quantity of geothermal energy supplied for consummers is around 60000 Gcal (Bococi 2005).

Material and Method. To establish the content of the major ions of the geothermal waters from the Oradea Triassic aquifer, the geothermal fluids were sampled and analyzed during six months (since October 2007 to March 2008), by using ion chromatographic method. In this period of the year, the geothermal installations are used at their maximum capacity.

There were made ion chromatographic (IC) analyses in order to evauate the content of the SO_4^{2-}, HCO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+ ions.

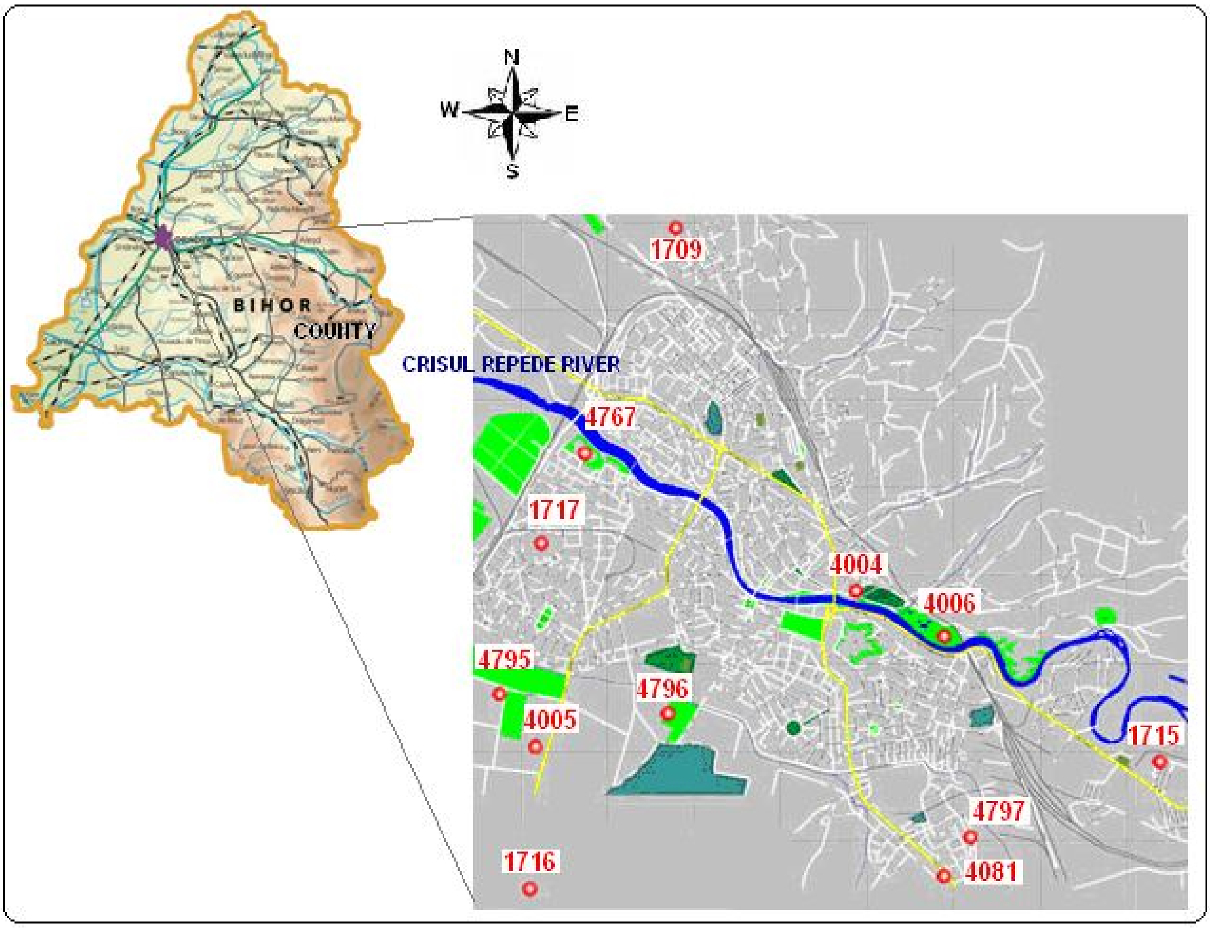

Figure 1. The location of the geothermal wells in Oradea perimeter (Bihor County) (Haiduc et al 2008).

Results. Chemical data shown the existance of a high similitude of the chemical composition of these waters, there for it is clearly the common origin, and the unitary recharging. Distinguishing between the hydrochemistry of these wells, we remark that an important characteristic of geothermal waters from Oradea is the highest content of sulphate, calcium and magnesium. The content of sulphate ion is about 350-900 mg/l, and 190-300 mg/l for the bicarbonate ion. The calcium content for hot waters is about 140-300 mg/l, and for magnesium is about 40-75 mg/l. Te sodium content is relatively low: 7 mg/l up to 117 mg/l, as the level of ammonia ion (0.1-4 mg/l). Like most of the geothermal fluids of meteoric origin, the Oradea geothermal fluids have low chlorine content (19-50 mg/l). In the Figure 2 and Figure 3 are presented the concentrations for these ions; the values represent the main concentration for a period of six months, between October 2007 to March 2008.

Generaly the geothermal waters from Oradea Triassic aquifer have the chemical composition of the contact rocks. One of the most important influence upon the chemistry of these waters is caused by the presence of the anhydrid (calcium sulfate $CaSO_4$), the proove is the high content of sulfate ions, around 900 mg/l. It is important to remark that in the last stratum the quantity of sulfur is increasing, it apears as calcium sulfate in anhydrid. Natural waters in their movement to the bottom of the collector meet charbonate rocks, which they dissolved in a closed system. In this way, the waters accumulate bicarbonate ions, calcium and magnesium. The contact with some clay stone justifies the presence of chlorine ion and the ions of some alkaline metals in these geothermal waters; nevertheless, the influence of the clay stone is insignificant (Liteanu et al 1965; Stănăşel 2003).

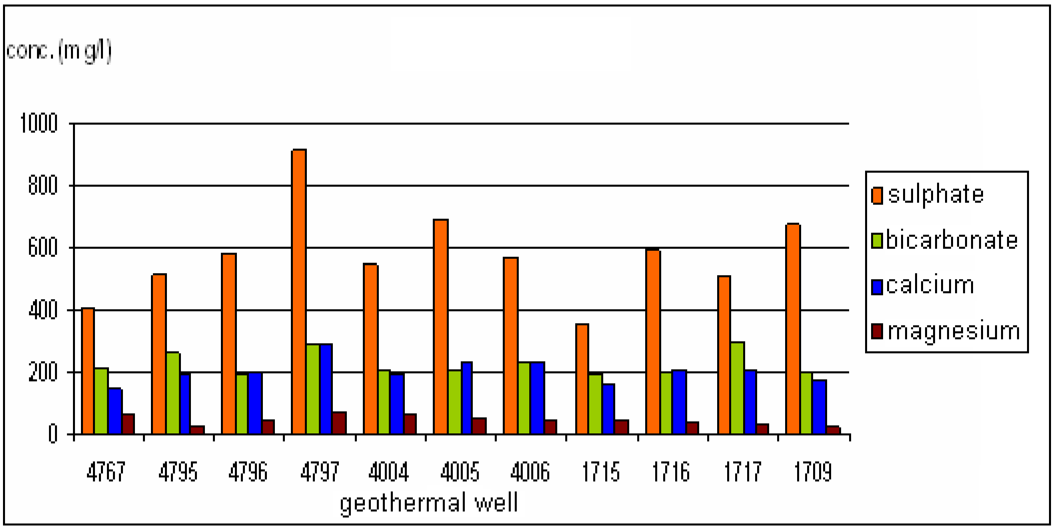

Figure 2. The sulphate, bicarbonate, calcium and magnesium mean concentration in the Triassic geothermal aquifer from Oradea (December 2007 - February 2008).

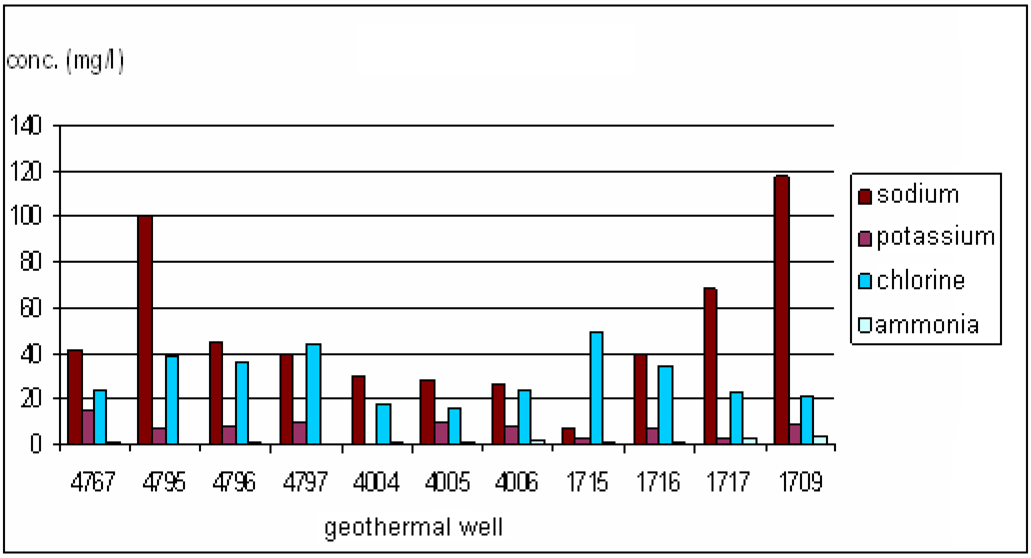

Figure 3. The sodium, potassium, chlorine and ammonia mean concentration in the Triassic geothermal aquifer from Oradea (December 2007 - February 2008).

The chemical characteristics of geothermal fluids from Oradea Triassic aquifer show that this water can be classified as sulphate-calcium-magnesium type, with no scaling or corrosion potential.

Mineralization of these waters is relatively low, between 1000-1300 mg/l, and the water hardness has values between 30-40°G. Thus, very seldom corrosion and crust phenomena appear in the geothermal water exploitation plumbing system. It was detected a clear interdependance between the ions concentration, and the total mineralization. In the Oradea Triassic collector it was noticed an increase of the sulfate ions in accordance with mineralization, while bicarbonate ions concentration is decreasing in accordance with the same parameter.

Conclusions. To establish the content of the major elements of the geothermal waters from the production wells from Oradea, the geothermal fluids were sampled and analyzed during six months (since October 2007 to March 2008), by using ion chromatographic method. Distinguishing between the hydrochemistry of these wells, we remark that an important characteristic of geothermal waters from Oradea Triassic aquifer is the highest content of sulphate ion (350-900 mg/l), bicarbonate (190-300 mg/l), calcium (140-300 mg/l) and magnesium (40-75 mg/l). Te sodium content is relatively low: 7 mg/l up to 117 mg/l, as the level of ammonia ion (0.1-4 mg/l). Like most of the geothermal fluids of meteoric origin, the Oradea geothermal fluids have low chlorine content (19-50 mg/l). The chemical characteristics of geothermal fluids from Oradea Triassic aquifer show that this water is sulphate-calcium-magnesium type, with no scaling or corrosion potential.

References

Airinei S., 1987 [Geothermics Applied to Romania]. Editura Stiinţifică şi Enciclopedică, Bucureşti, Romania. [In Romanian]

Bobin J. L., Huffer E., Nifenecker H., 2005, [The Energy of Tomorrow] L' Énergie de demain. Techniques, environnement, économie. EDP Sciences, Grenoble. [In French]

Bococi D., 2005 [Geothermal Energy: Complex Utilization]. Editura Universităţii din Oradea, Romania. [In Romanian]

Brown K. L., 2000 Impacts on the physical environment. In Brown K. L., (ed.), Environmental Safety and Health Issues in Geothermal Development, WGC 2000 Short Courses, Japan, 43-56.

Cohuţ I., 1986 [Hydrogeothermal system Oradea-Felix]. Anuar Crisia 16:616-628. [In Romanian]

Cohuţ I., Bendea C., 2000 Romania update report for 1995-1999. World Geothermal Congress 2000, Japan.

Commission of the European Communities, 10.1.2007 COM (2006) 848 final Communication from the Commission to the Council and the European Parliament, Renewable Energy Road Map, Renewable energies in the 21st century: building a more sustainable future, {SEC(2006) 1719}, {SEC(2006) 1720}, {SEC(2007) 12}

Commission of the European Communities, 23.1.2008 COM (2008) 30 final, Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy fron renewable sources, {SEC(2008) 57}, {SEC(2008) 1720},{SEC(2007) 85}.

De Alegria-Mancisidor I. M., de Basurto-Uraga P. D., de Alegria-Mancisidor I. M., de Arbulo-Lopez P. R., 2009 European Union's renewable energy sources and energy efficiency policy review: The Spanish perspective. Renewable and Sustainable Energy Reviews 13:100–114.

Dickson M. H., Fanelli M., 2004 What is Geothermal Energy? International Geothermal Association, information available at http://iga.igg.cnr.it

Haiduc I., Roba C., Olah S., Horga C., Păuşan D., 2008 [The chemistry of the geothermal waters from Oradea Triassic Aquifer]. Environment & Progress 12:187-190. [In Romanian]

IEA (International Energy Agency). Available online, last view: 03.01.2009, http://www.iea.org/pubs/studies/files/benign/pubs/appedn3g.pdf

IGA (International Geothermal Association). Installed Generating Capacity, available online, last view: 03.01.2009 http://iga.igg.cnr.it/electricitygeneration.php

Liteanu E., Vasilescu G., Oprean C., 1965 [Fundamentation of hydrogeological research for discovery of new sources of hyperthermal water in the Western Plain of the Country]. D. S. Inst. Geol., vol. LI/2, Bucureşti. [In Romanian]

Lund J. W., Freeston D. H., 2001 World-wide direct uses of geothermal energy 2000. Geothermics 30:29-68.

Stănăşel O., 2003 [Chemical monitoring of the productive geothermal drills]. Editura Universităţii din Oradea, Romania. [In Romanian]

Țenu A., 1981 [Hyperthermal water deposits from North-West of Romania]. Editura Academiei R.S.R., Bucureşti, Romania. [In Romanian]

Zaharia C., 2004 [Energy and Environment]. Editura Universităţii "Alexandru Ioan Cuza", Iaşi, Romania. [In Romanian]

*** 2001 Energy Information Administration. Renewable Energy Annual 2001, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/table5.html
*** http://www.repp.org/geothermal/geothermal_brief_environmental_impacts.html
*** http://www.geothermal.marin.org/map/easteurope.html
*** http://www.agir.ro/univers-ingineresc/energia_geotermala_1664.html

Received: 03 January 2009. Accepted: 20 January 2009. Published: 30 January 2009.
Authors:
Ruxandra Mălina Petrescu-Mag, Babeș-Bolyai University, Faculty of Environmental Sciences, 30 Fântânele Street, Cluj-Napoca 400327, e-mail: pmalina2000@yahoo.com
Carmen Roba, Babeș-Bolyai University, Faculty of Environmental Sciences, 30 Fântânele Street, Cluj-Napoca 400327, e-mail: roba20012002@yahoo.com
Dacinia Crina Petrescu, Babeș-Bolyai University, Faculty of Business, 7 Horea Street, Cluj-Napoca 400174, e-mail: crina.petrescu@tbs.ubbcluj.ro
How to cite this article:
Petrescu-Mag R. M., Roba C., Petrescu D. C., 2009 The Romanian perspective on geothermal energy resources. The chemistry of the geothermal waters from Oradea Triassic aquifer. AACL Bioflux 2(1):9-17.
Printed version: ISSN 1844-8143
Online version: ISSN 1844-9166 available at: http://www.bioflux.com.ro/docs/2009.2.9-17.pdf