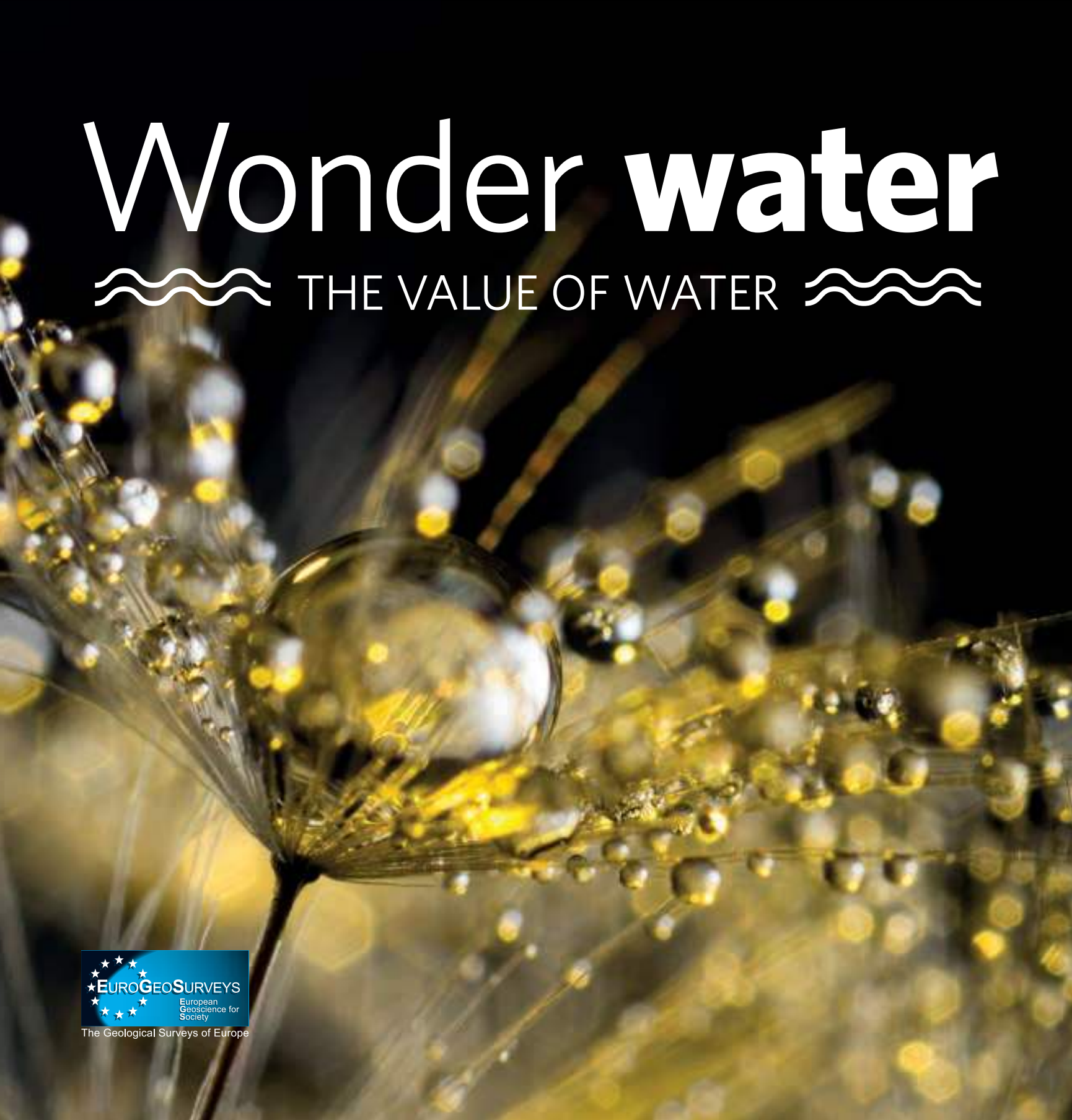
Wonder **water**

THE VALUE OF WATER



EUROGEOSURVEYS
European Geoscience for Society
The Geological Surveys of Europe

"We forget that the water cycle and the life cycle are one."

Jacques Yves Cousteau

I am delighted to welcome you to this publication Wonder of Water, from EuroGeosurveys , and hope you will enjoy it. It represents the latest in a series of publications we have produced, which aim to provide a simple and easy to read guide to key aspects of Geoscience, and how this impacts on our normal lives. In the case of water and in particular groundwater or the water beneath our feet it is unfortunately sometimes a case of "out of sight, out of mind". We do not often think about where our water comes from, how it formed and how it is stored, and more importantly now, how it is protected.

This publication aims to show how our groundwater is used and enjoyed across Europe, in examples selected by the different Geological Surveys. It is the role of the national and regional Geological Surveys to define where groundwater exists, in underground aquifers, and how it should be protected, by mapping the shallow and deep subsurface and producing planning tools such as Groundwater Protection Schemes. These maps and models can then be used as planning tools by the relevant local authorities and government bodies to protect water supplies and comply with EU regulations such as the important Water Framework Directive. This work is reflected in the knowledge of the groundwater geologists who form the Groundwater Expert Group of EuroGeoSurveys and who have compiled the chapters of this book and I wish to this the chance to thank them for their work in compiling this interesting volume. Secondly I must thank the work of EuroGeoSurveys communications staff, who carried this project from inception to completion and in particular Claudia Delfini. Finally thank you the reader, for picking up this book, which I hope will educate you, entertain you and leave you with an appreciation for the water beneath your feet!

Koen Verbruggen
President
EuroGeosurveys

Introduction

What is groundwater?

The ground below our feet acts as a vast store of water, nearly 30% of all freshwater resources on earth are found underground. This 'groundwater' exists in the pores between grains of rock or soil, within fractures in the rock, or even in large cave systems. Groundwater originates as rainfall or snowmelt that soaks into the ground continuing downwards, under the influence of gravity, until it reaches a zone in which all the available spaces are saturated with water – the top of this zone is called the water table. The level of the water table varies across different terrains, climates and rock types, and over time. Rocks that store and transmit important quantities of groundwater and provide critical resources are called aquifers.

It has been estimated that 75% of European Union residents depend on groundwater for their water supply. Groundwater is particularly good as "potable" water (water fit for consumption by humans) because it is filtered naturally as it moves through the rock and soil, therefore needing less treatment when used as a source of drinking water.

Nowadays technology enables large quantities of groundwater to be pumped from aquifers but in the past people relied on natural sources of groundwater emerging at the ground surface, in the form of springs - natural openings for water in the ground.

Historically groundwater often in the form of natural springs or hand dug wells provided a vital supply of potable water. In countries with Mediterranean climates where surface water flow could not be relied upon, springs could provide a reliable year round source of water. Springs can also provide more stable water quality than surface waters and it is perhaps this ability to provide both a reliable quantity and quality of water that have led to springs becoming focal points for a range of communities with many springs gaining spiritual or religious significance.

How do springs form?

Springs can be found across the globe and occur where the water table meets the land surface. This is controlled by a variety of factors associated with the geological landscape and evolution of a given area.

Springs can often be identified on the land surface because they form a pool or start of a stream. Younger (2007) summarises the key settings where a spring is likely to form

- where the ground surface cuts below the water table so the water in the aquifer can seep out. This often happens in valleys;
- where a permeable aquifer and an impermeable unit of rock are adjacent to each other groundwater cannot flow any further through the ground and is forced out as a spring;
- where a geological fault fractures the rock and increases the permeability, forming a pathway for water to flow. These may be present in tectonically active regions where rock is being actively deformed, or in previously deformed regions;
- where weathering processes have dissolved rocks leaving large voids. This particularly occurs in carbonate rocks such as limestone. Very large springs (with high flow rates), are often associated with such features, with cave systems being a good example.

Groundwater for health and wellbeing

There are many types of springs, perhaps the best known being thermal and mineral springs. A spring is considered to be thermal if the water is warmer than the average air temperature of the region and is heated naturally by the earth. This temperature can range from 10-12°C in Northern Europe to over 103°C in Sapareva Banya, Bulgaria. Many thermal springs also have a high mineral content. It is the presence of minerals that led some to believe that these springs are particularly beneficial to wellbeing.

The thermal properties and mineral content of some springs are thought by some to have health benefits over and above providing a clean drinking water source. Many mineral springs have a high proportion of dissolved minerals in the water (over 1000 milligram per Litre, mg L^{-1}).

Mineral and thermal springs have been revered across Europe for over 4000 years. The remarkable parallels across the continent reflect our entwined history. The Romans were the first to capture and develop thermal and mineral springs on a large scale, establishing a great number of advanced bathing systems across their Empire. Little is known about the use of the springs after the collapse of the Roman Empire, though it is assumed they remained in use albeit on a smaller scale. Around the 16th Century European nobility would travel long distances to "take the waters" in the form of bathing or drinking, to cure a range of ailments. In some places Royal Decrees were announced, promoting the use of the springs for common people. The original Spa (Salus per Aquam in Latin, meaning health through water) was established at this time in the Ardennes Hills of present day Belgium. More recently health and wellbeing tourism flourished with the advent of railways and public transport which allowed people to travel more easily.

Taking the waters was prescribed as a cure from a wide range of diseases or infirmities in pre-scientific medicine and particularly for the rehabilitation of soldiers. Balneotherapy, the treatment of diseases, injuries and other ailments with bathing, often in mineral waters of different temperatures, is still prescribed in some countries as a complement to modern medicine. More commonly mineral and thermal waters are considered to contribute to wellbeing through relaxation from recreational use (swimming pools and water parks) to health spas, and people will travel many miles for authentic natural experiences. A report by the Global Wellness Institute in 2014 estimated that there are over 5000 spas in Europe providing treatments using thermal and mineral spring water, with an annual revenue of nearly €21.7 billion – the second largest market in the world behind Asia. Sixteen of the top twenty revenue-generating countries from thermal and mineral waters were in Europe, with Germany, Italy, Austria, Turkey, Hungary, Czech Republic and Spain all within the top ten.

While drinking mineral waters directly from springs has decreased in popularity, the 1980s saw the burgeoning of the bottled water market, heavily promoted by marketing campaigns. Mineral waters, many of earlier renown, are now bottled at the source and sold for drinking. Water sold as natural mineral water must have a stable composition over time, and be minimally treated and free from pollution. A European Directive 2009/54/EC controls the exploitation and marketing whist a separate Directive 2003/40/EC establishes the concentration limits and labelling requirements for natural mineral waters.

The total volume of bottled water consumed in Europe is more than 50,000 m^3 a year, more than any other continent, or an average of 60 liters per person per year, though this differs widely between countries. The bottled water industry is still continuing to grow at a rate of 5-10% per year. Italy has the highest consumption in the world of bottled water per capita, with a consumption of 184 Liters each year, but Belgium and Luxembourg, France, Spain, Germany, Switzerland, Cyprus, Czech Republic, Austria and Portugal all feature in the top 15 per capita consumers of bottled water. A number of reasons have been posed for this trend including concerns over tap water quality (though not a great concern in Europe), convenience and preference for taste as tap water is often treated with chlorine which gives it a distinct smell.

Down to the geology

Geology has a major impact on both the composition and temperature of mineral and thermal springs, but also where they occur and how much water is discharged. The nature of thermal and mineral springs varies widely across Europe, reflecting its wide geological diversity. The European landmass is part of the Eurasian continental plate which is colliding in the south with the northwards moving African plate. This convergence has resulted in the formation of the Alp-Carpathian mountain range, which spans from southwest France in the west through to Romania in the east and also the Pyrenean mountain chain along the Spanish/French border. Below Greece and Turkey two smaller plates, the Aegean and Anatolian plates, separate the African and Eurasian plates. The subduction of the African plate under the Eurasian, Aegean and Anatolian plates results in a number of volcanoes in Italy and in the Mediterranean and Aegean seas.

To the west and north the Eurasian plate is moving away from the North American plate, creating new crust. Except for Iceland, where new land is being continuously formed through volcanic activity, this process occurs far from the European continental land mass. The northern European plains extend from northern France and eastern England through to the Ural Mountains that run north-south through western Russia. The plains are bound to the south by the relatively young southern European mountain ranges and to the north by the older highlands of northern Europe

TDS (mg L^{-1})	Water classification
Less than 1000	Fresh
1000 to 10,000	Brackish
10,000 to 100,000	Sea water
More than 100,000	Brine

Table 1: Categories of water based on Total Dissolved Solids.

Introduction

Major ions > 5 mg L^{-1}	Bicarbonate	Chloride	Sulphate
	Sodium	Calcium	Magnesium
Minor ions 0.01-10 mg L^{-1}	Nitrate	Carbonate	Fluoride
	Phosphate	Potassium	Strontium
	Iron	Boron	
Trace constituents (< 0.1 mg L^{-1})	Aluminium	Arsenic	Barium
	Bromide	Cadmium	Caesium
	Chromium	Cobalt	Gold
	Iodide	Lead	Lithium
	Manganese	Nickel	Phosphorous
	Radium	Selenium	Silicon
	Silver	Thorium	Tin
	Titanium	Uranium	Vanadium
	Zinc		
Dissolved gases (trace to 10 mg L^{-1})	Nitrogen	Oxygen	Carbon dioxide
	Methane	Hydrogen sulphide	Nitrous oxide

Table 2: Components of groundwater, from Davis and DeWiest (1966)

Type of spring	**Apparently active solutes**	**Ailments for which the spring has perceived benefits**
Saline	Sodium, chloride	Gout and rheumatism
Radioactive	Uranium, radium, radon	Rheumatism and arthritis, heart, cancer
Alkaline	(Bi) carbonate	Rheumatism, skin diseases and digestive disorders
Sulphur	Sulphide	Eczema, skin diseases, respiratory, gastritis, heartburn, bladder and kidneys, rheumatism, gout, nerves
Soda springs	Carbon dioxide	Indigestion
Chalybeate	Iron	Infertility, anaemia, hangovers, obesity and general debility
Magnesium	Magnesium	Eczema, skin diseases, respiratory, gastritis, heartburn, bladder and kidneys, tubercular diseases

Table 3 Classifications of mineral and thermal springs, significant composition and perceived benefits e.g. Robins and Smedley (2013)

which extend through the west of the British Isles, Ireland, Scandinavia and Iceland.

The warmest thermal springs are usually found close to plate boundaries or volcanoes where the earth's hot mantle is closer to the ground surface. Here the geothermal gradient (the increase in temperature with depth) can be very high. For example, in some places in Iceland the temperature of the earth increases by at least 160°C with each kilometre depth into the earth. Thermal springs here can be above boiling point. However, most of the continent is away from tectonic plate boundaries and temperatures increase at a much lower rate – by about 25°C with every kilometre depth. Thermal waters in these areas tend to have flowed much deeper within the earth's crust although some rocks such as granite and uranium rich "hot" shales, also generate their own heat through the radioactive decay of elements. A range of chemical and physical scientific techniques allow us to trace the pathways of groundwater and it is possible to determine the age of groundwater – the time since the rainfall soaked into the ground. Some mineral waters have been shown to be up to 10,000 years old. Faults are often important for bringing these old waters back to the surface.

Something in the water

Pure water, comprising only H_2O molecules, does not exist in nature. All natural water has additional components, including dissolved minerals. The composition and mineral content of groundwater can differ considerably between locations. Mineral content predominantly reflects host rock composition, though the composition of rainfall and soil will also provide a small contribution. Over time groundwater will dissolve certain minerals from the rock it flows through.

The total mineral content in water is expressed as Total Dissolved Solids (TDS) (in mg L^{-1}). Table 1 shows water types with differing TDS ranges. Historically water with very high mineral content, such as the Karlovy Vary springs in the Czech Republic with a TDS of 6400 mg L^{-1}, were considered beneficial if either consumed or bathed in. Nowadays water with such high TDS is rarely consumed and bottled waters tend to have a TDS lower than 1000 mg L^{-1}. Water with TDS 2000-3000 mg L^{-1} is often considered too salty to drink (Table 2), although a few mineral waters approach 3000 mg L^{-1}.

The most common components in groundwater (listed as major ions in Table 2) normally comprise more than 90% of the TDS. Other dissolved minerals may be present but in smaller quantities. The combination of minerals present in the water will impart a particular taste and/or smell, for example water with a lot of minerals might have a salty taste, iron a metallic taste, and hydrogen sulphide a smell of rotten eggs. The specific minerals found in groundwater often reflects the rock types that it has flowed through.

For example, water that has flowed through limestone, a rock composed of calcium carbonate ($CaCO_3$), often has a high proportion of calcium bicarbonate (Ca-HCO_3) dissolved within it. Crystalline metamorphic or igneous rocks contain mostly silicate minerals which are slow to react and result in groundwater with very low TDS overall.

Springs with a high content of specific dissolved minerals have historically been promoted as cures for certain ailments (Table 3), even those with radioactive components. Thermal springs are considered to provide an additional aspect of relaxation due to the temperature, but they also often have a high TDS since warmer temperatures can speed up reactions.

Future vistas (pressures and protection)

European mineral and thermal springs have prevailed for thousands of years and should continue for thousands more. Yet our actions have the potential to impact on these resources by either affecting water flow or quality.

Commercialisation of springs for drinking and as bathing are placing greater demand on the resource. In many cases pumping has superseded natural discharge, which, if not properly monitored can be unsustainable. Land-use change, including deforestation, intensive agriculture and urbanisation are frequently cited as concerns in terms of potential to impact groundwater resources and chemical quality. In some areas, the water table in the aquifers that the springs discharge from are purposefully lowered to allow excavations for mining or building.

Introduction

Pollution from cities or agriculture can also be a concern, particularly for drinking water quality, although protection is afforded to all groundwater bodies through the European Water Framework Directive (2000/60/EC), which is implemented by each Member State and requires good water status to be achieved for all groundwater bodies. This however cannot easily mitigate against the impacts of changing climates and recharge to aquifers that may occur in the next 50 to 100 years. Sources of bottled water are required to be protected to a high standard since they cannot be treated before bottling. As for other drinking water, source protection zones have been implemented around important groundwater abstractions with the aim of regulating and protecting resources and quality in a sustainable manner. However, concerns exist around shared equity of groundwater and commercialisation of public resources. The wastefulness of the bottled water industry must also be balanced against commercial interests since it requires some 5.6 to 10.2 MJ per litre, 2000 times the energy required for producing tap water. It is also up to 1000 times more expensive than tap water.

Throughout history thermal and mineral springs have influenced and shaped different cultures, the growth and development of communities and contributed to their health and well-being. Despite the many changes that have taken place over time they continue to play a significant role in society. Some have been afforded special conservation status by being designated as UNESCO World Heritage sites and others are protected specifically under European Directives. It is very clear that the importance of these natural features will continue to be valued by society and provided that they continue to be protected will provide enjoyment for generations to come.

Sian Loveless, Gareth Farr, Rob Ward & Pauline Smedley

British Geological Survey
Maclean Building, Crowmarsh Gifford,
Wallingford, Oxfordshire, OX10 8BB

Sian Loveless is a hydrogeologist at the British Geological Survey. Her research interests include faults and fluid flow, hydrogeological rock properties and geothermal energy.

Gareth Farr is a hydrogeologist at the British Geological Survey, based in Wales, UK and previously worked for Environment Agency Wales. Gareth's research interests range from characterising how groundwater supports and influences wetlands to assessing the potential for ground source heating from abandoned mine workings and shallow urban groundwater systems.

Rob Ward is Director of Science for Groundwater at the British Geological Survey. Rob has research interests in environmental policy and regulation and represents the United Kindom on the Water Framework Directive expert advisory group for groundwater.

Pauline Smedley is a hydrogeochemist with the British Geological Survey, with interests in the chemistry of groundwater and drinking water and the processes that determine it.

Austria

Introduction

In Austria the major well-being effect of groundwater is based on the excellent quality of its clean and refreshing drinking waters. Everyone can open his water tap at home and consume cool precious water. This applies especially to the bigger cities. They often get their drinking water from springs in the mountains. The most famous example are the “First and Second Vienna Mountain Springs Pipelines” (“Wiener Hochquellen-wasserleitungen”).

Irrespective of cool drinking water, in Austria also its mineral waters and thermal waters contribute to wellness and health, even since Roman times. The occurrence of mineral waters and in particular the thermal waters is the result of special geological structures. This article deals mainly with the Austrian thermal waters. It gives an overview of the resources’ distribution as well as their utilization, their economic value and protection.

Next year the Geological Survey of Austria will publish a hydrogeological map on Austria’s thermal waters with comprehensive explanatory notes including geological cross sections, drilling profiles, quantitative aspects, hydrochemistry, isotope hydrology and history.

Why it is special and why it is good for our well-being?

In general, thermal waters are connected with special geological situations. The profitable exploitation of new thermal water wells is a risky business and demands a lot of geological and technical know-how.

In Austria the most extensive and productive thermal water resources are bound to deep geological structures in basins. In detail these are the foreland basin in front of the Alps (Molasse Basin) and the big Alpine intramontane basins (Vienna Basin, Styrian Basin and the Austrian part of the Pannonian Basin). In some regions the sedimentary filling of these basins has a thickness of few thousands meters. These sediments are mostly marine deposits and have a low permeability in general. In spite of this, within permeable rocks below these sediments, free water convection can arise and thermal water can be generated. This principle of causation was detected by drilling for hydrocarbons. Thermal waters from formations below the bottom of the deep sedimentary basins can be reached in the ascending springs on the basin margins or by deep boreholes. This kind of thermal springs are well-known for a long time. The so-called "Thermenlinie" ("thermal line") in the Southern Vienna Basin with the spas in Baden, Bad Vöslau and Bad Fischau on the western margin of the basin are the most popular examples for this type of origin. Especially in Baden thermal waters are used since long time (see below).

The exploitation history of thermal waters in the deep parts of the basins is connected with the oil exploration. In the Vienna Basin the thermal water of Oberlaa in Vienna ("Therme Wien") was discovered by drilling for hydrocarbons. The same is true with several thermal water occurrences in the Styrian Basin and in the Molasse Zone, where for instance the water of Bad Schallerbach was used already in 1918.

Apart from this, thermal water occurrences of another, more local type are situated within the Alps, in areas where water is able to infiltrate deep into the mountains. Getting heated in deep formations the water rises again along special geological features and is discharged as thermal springs in deep valley cuts. The most important representatives are Bad Gastein, Bad Kleinkirchheim and Warmbad-Villach. The latter was used already by the Romans.

Thermal water can be used, besides the generation of geothermal energy, for two purposes:

1) for leisure activities (swimming, bath or wellness resort) and

2) for medical issues (balneology). Nowadays the importance of the second purpose is increasing due to the rising age of people. Balneotherapy has become an important sector in rehabilitation.

In Austria the licensing of natural medical springs for sanitary purposes is regulated by the health resorts acts (Heilvorkommen- und Kurortegesetz) of the individual federal states. Only those waters can be named as a "natural medical spring" which have got a licence from the authority. According to this law, one reason for getting a licence is the water temperature which has to be at least 20 °C at the surface. Furthermore this law lists special dissolved contents. The occurrence of one or more of those is needed for getting a licence. These are certain minimum amounts of total dissolved contents, of carbon dioxide, of iron, of iodine, of sulphide and of radon. Beyond that, additional pharmacologically active substances can be accredited. Waters which have been licenced as natural medical springs are assumed to have a scientific approved medical benefit.

Use of the resource

In Austria thermal waters are mostly used by swimming baths, wellness resorts and therapeutic baths. Today there exist around 40 thermal spas. Several of them offer facilities for leisure activities as well as balneotherapy. For instance, in 2011 the Austrian thermal spas had 8.5 Million visitors. But thermal water is not only used for spas. In the Molasse Zone there exist also some district heating plants which operate with thermal water. In few cases also some amount of electricity is generated by the use of hot thermal water.

Some special features of thermal water usage are the production of mineral water and even beer. In Bad Vöslau low mineralised thermal water is getting bottled and in Graz thermal water with low amounts of dissolved contents is used for brewing beer. As these thermal waters stay for a long time in the aquifer they are well protected against man-made contamination.

Austria

Threats and protection

Since the nineteenth century the threat to thermal waters was a subject of legislation in Austria. In 1879 the city of Baden near Vienna (see below) became the first Austrian protection area for thermal waters. At this time this was subject of the mining law (Amtsblatt zur Wiener Zeitung Nr. 295, December 20th, 1879). In later times the protection of thermal water resources was an issue of the water law. Today there exists also an international contract between Germany and Austria concerning the thermal water usage in the Molasse Zone in the Bavarian-Upper Austrian region. Modern protection zones include the monitoring of the thermal waters' quantity and quality. The data have to be delivered to the water authority. Furthermore, new thermal water projects have to be licensed by this authority.

Myths or stories

Austria's most important historical spa is located in the city of Baden near Vienna. In the time of the Roman imperator Claudius (41-54 AD) it was called Aquae. There were baths, a civil city and vineyards for the soldiers of the X and XIV Roman legion. In the early Middle Ages the locality was called Padun.

During the Austrian imperial period Baden was developed as glamorous bathing resort. In the sixtienth century the governor of Lower Austria, Christoph von Schallenberg, composed the song "Why the Badenian water would be so warm". In this song he explained that the torch of the sleeping Amor heats the spring water of Baden. As a consequence this water makes many cold hearts burning.

Geological Survey of Austria

Gerhard Schubert is a geologist and hydrogeologist of the Geological Survey of Austria in Vienna. His team is working on regional studies on groundwater resources and geothermal issues in the whole country and in the international context. In particular, he deals with the compilation of national hydrogeological databases, maps, and its explanatory notes.

Belgium

Introduction

Spa, the 'water city' in Belgium, can be considered one of the birthplaces of thermalism. At the climax of its development during the 17th and 19th centuries, the city was widely associated with frequent curative visits by European Gotha members. In turn, those royals and that fame spread the name of this small city on the edge of the Ardenne hills, now synonymous with thermalism, across Europe and beyond.

Before this international recognition, Spa village's toponym was already derived from its spring waters and their wellness benefits. The most frequent explanations come from different Latin translations, such as 'Salus Per Aquam' meaning health through water; or from 'Spargere', to sprinkle, gush; or even from 'Sparsa Fontana', gushing fountain. Later, the old French term 'Espa' denoted a fountain, while in the local Walloon dialect, 'Spatia' indicated an open space.

Beside this glorious history, the city of Spa is today still associated with its natural water resources. This profound link between Spa and water can even be found, surprisingly, in places such as the 'Spa-Francorchamps' racing circuit, where Formula 1 cars speed into famous sections, like 'l'Eau Rouge' ('Red Water'), 'Pouhon' (a dialectic word for ferruginous sparkling water springs) and 'de la Source' ('of the Spring').

Why it is special and why it is good for our well-being ?

The Spa area includes 16 different springs. Among the most famous are the Pouhon Pierre le Grand, the Sauvenière, the Geronstère, the Groesbech, the Barisart, the Tonnelet, the Reine and the Clementine catchments. They belong to two distinct groups: cold ferruginous and carbogaseous springs (named 'Pouhons') and cold oligometallic (low mineral) springs.

Three mains sources for Spa's thermal cures are the Clémentine, Reine and MarieHenriette springs. The Clémentine's calcium bicarbonate water, taken by ingestion, purifies the liver and facilitates digestion. The less-mineralised water of the Reine catchment arises from its demineralised 500-million year-old Cambrian bedrock. This water allows intensive rehydration, diuresis treatment, and is perfect for low sodium diets, with only 33 mg of minerals per litre. This water in particular is extensively marketed in Belgium and beyond its borders by the Spa Monopole firm. Finally, the Marie-Henriette spring is the oldest and the most famous of Spa's waters. Faults allows adjacent very old natural mineral waters, to be brought to the surface in the form of an emulsion in dissolved gas (HCO_3). This gas primarily originates from the decomposition of marine carbonates located at great depth. It is a naturally sparkling, iron- and manganese-bearing carbonated water. Its mineral properties mean it is used as an anti-inflammatory (for joint pains, rheumatism, etc.); for respiratory diseases by inhalation due to the sulphur contained in the water; and against cardiovascular diseases. The Marie-Henriette water comes from 3 catchments, which share the same attributes and originate from the same aquifer: Marie-Henriette, Wellington and Tonnelet.

Use of the resource

The Spa sources are used for both external and internal cures. These cures combine the Reine water (rich in calcium and sodium), with the water from ferruginous and carbogaseous springs and the peats (from the Hautes Fagnes region). Peat results from the slow decomposition of subalpine material, primarily sphagnum (marsh, or peat, moss). In the Hautes Fagnes, peats are very old, so the process of degradation is pushed to the maximum. Thanks to their high acidity and the presence of abundant assets, the peat is very beneficial. External treatments imply peat baths, carbonic baths (in copper baths) and jet showers. Internal treatments concern in essence a drinking treatment (against anaemia) and inhalations (diseases of the nose, throat and respiratory tract). In the latter case, the active agent is the sulphur content of the water. The spas in Spa also apply hydrotherapy techniques, massage, physiotherapy and re-education. The main use of Spa waters is drinking, through the many varieties of spa water bottled by the Spadel Group. This group is the European leader for Benelux and owns other brands, such as Bru (Ardenne), Brecon Carreg (Wales), Wattwiller and Carola (Alsace). Since 1921, Spa Monopole, a daughter of the Spadel group, has been exploiting Spa's resources. Located in the Spa town centre, it is the largest bottling firm for soft drinks in Belgium. The Spa sources used are the Barisart source (sparkling, by adding carbon dioxide), the Marie-Henriette source (naturally sparkling) and the Reine source (still water) with more than 75 million bottles per year. The Sothys Paris group operates the SPA brand cosmetic range for sensitive skin, made from Spa Marie-Henriette mineral water.

Threats and protection

Considered a national treasure, the scope of sources was subject to strict protection early on. A law from 1 August 1924 states that the government can recognize a source of public utility after notice by the Academy of Medicine and securing a perimeter of protection. More than 300 sources were identified at Spa, spread over the entire municipality.

Some remain today, fortunately valued and preserved. A surveillance zone covering an area of 13,177 hectares was created for the protection of Spa mineral waters, making it one of the largest water protection areas in Europe. In 2008- 2009, Spa natural mineral water obtained the first European Mineral Water Quality Prize. Environmental quality assurance for this large protected area is currently conducted by more than 400,000 monitoring agents: bees! Eight colonies were implemented in the framework of the BeeSpa project, conducted by the BEEODIVERSITY association and Spa Monopole over the protection area. The pollen and nectar collected by bees allows evaluation of the evolution of biodiversity as well as verification of the absence of any pollutants.

Belgium

Myths or stories

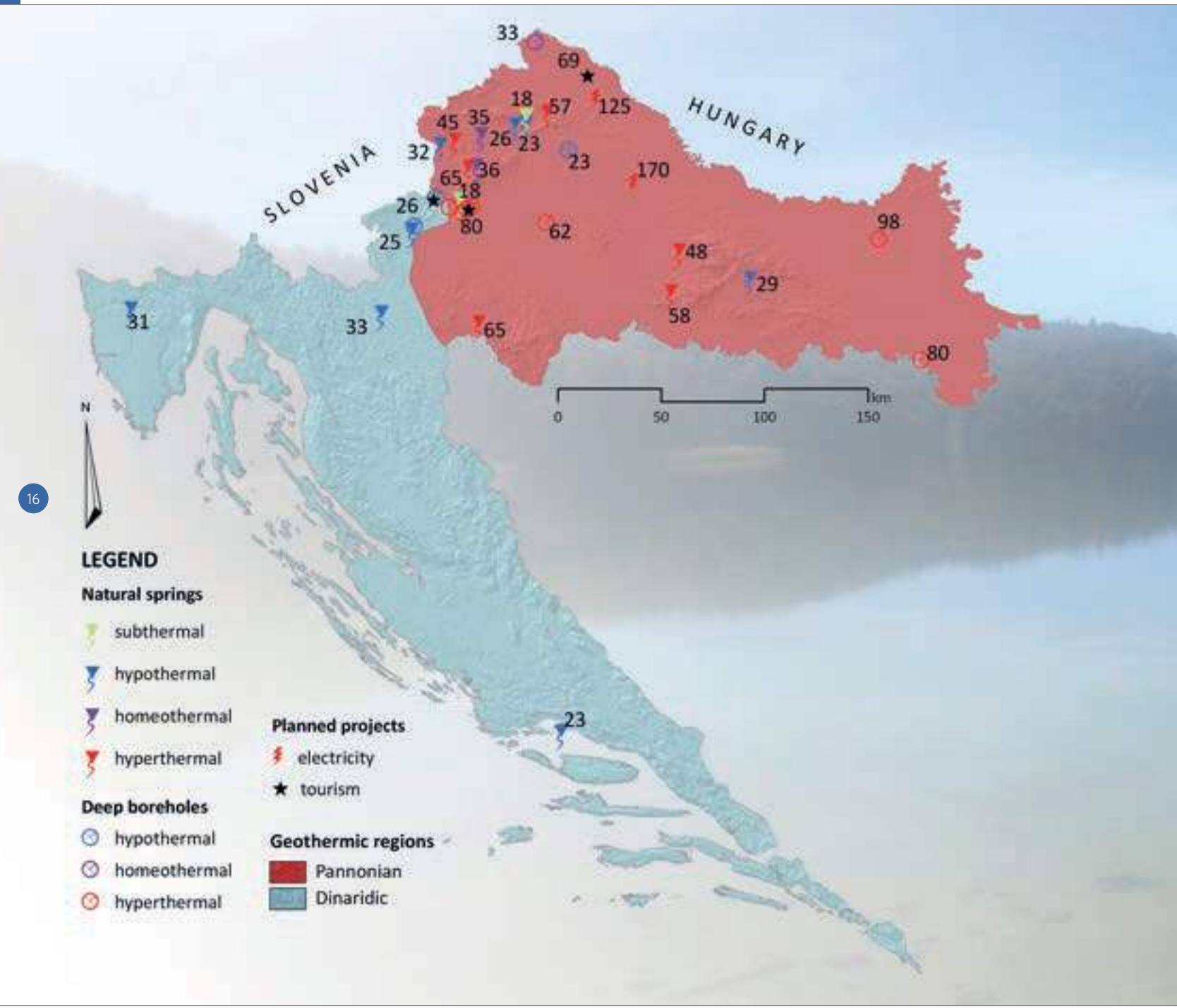
In antiquity, some iron springs were known for their healing qualities. People bathed in them and drank from them (or both). Pliny the Elder referred to Belgian sources in Natural History: 'In Tongrie, country of Gaul, there is a famous fountain whose water, while sparkling bubbles, has a ferruginous taste, which is, however, felt that when we finally drink. This water purges the body, cures fevers and dispels calculous affections. The same water, put to fire, becomes cloudy and then blushed'.

At the beginning of the 16th century, Spa was a tiny village in the heart of the forest at the border of the Hautes Fagnes, and would have remained insignificant without its water sources. Around 1540, there was upheaval. The Venetian Augustin, personal doctor to Henry III of England, then affirmed the therapeutic effect of the 'Pouhons'. These 'Pouhons' (meaning in the regional dialect ferruginous mineral source) made Spa famous. After that declaration, Spa was invaded by European personalities such as Charles II of England, writer Victor Hugo, the philosopher Descartes, Queen Christina of Sweden and Tsar Peter the Great of Russia in 1717 (to cure his stomach there), the Emperor Joseph II and the Prince of Orange. The second Belgian Queen, Marie-Henriette, stayed there from 1895 until her death in 1902. At that time, the cachet of a thermal city (later called spa) was based on the interest of the royal family for its attraction. The eighteenth century was the golden age of the town of Spa, called then 'Café de l'Europe', and thereafter renamed by Emperor Joseph II. The entire beautiful European world visited Spa to take the waters. It is at this time that the city obtained leisure and games facilities. The Spa Casino, the oldest in the world, was built by the Prince-Bishop of Liège, Jean of Bavaria, in 1762. During the second half of the 19th century, Spa adopted a thermal infrastructure still visible today. It was at this time that the establishment of 'Thermes de Spa', with 54 baths equipped to open in 1868, was built. The 20th century marked the economic decline of Spa. Decrease of the popularity of spas was also a general phenomenon in Europe. Attendance by the upper middle class was still present until the Second World War. After the war, mandatory social security transformed bath attendance. As thermal treatments were reimbursed, everyone could afford a natural therapy. People needed these therapies because many health problems caused by war (e.g. development of cardiovascular and rheumatic diseases) could thus be effectively treated. These cures were repaid in the 70s, which is hailed as the time of social hydrotherapy. However, from 1987, the hydrotherapy social service was no longer regarded as a hospital service, thus reducing the compensation amounts awarded for a cure. Since 1995, cures in Belgium are no longer reimbursed. Currently, health establishments speak of 'two-speed thermalism in Europe, as France, Italy, Luxembourg and Germany still have a reimbursement system. Nevertheless, Spa remains one of the most important tourist centres in the Ardenne.

Geological Survey of Belgium

Yves Vanbrabant, PhD in Geology and Mineralogy, is the Acting Director of the Geological Survey of Belgium (GSB). His field of activities covers mainly applied geology projects related to: the characterisation of mineral resources and the development of new tools/ concepts (hardware & software) for Geologists in the Research-Development team at GSB.

Estelle Petitclerc is Geologist, researcher at GSB in charge of geothermal energy. Her projects concern thermal characterisation of subsoil, shallow and deep geothermal potential and assessment of low carbon society policy instruments. She is also member of Walloon association for deep geothermal Engery (AGEOP) and of the GeoEnergy Expert Group of EGS.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subthermal
hypothermal
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hyperthermal
Deep boreholes
hypothermal
homeothermal
hyperthermal
Planned projects
electricity
tourism
Geothermic regions
Pannonian
Dinaridic
23

Croatia

Introduction

Croatia is a country with significant water resources, taking into account its climate, hydrologic and hydrogeological characteristics and demographics. According to UNESCO research on water reserves, which included 188 countries, Croatia ranked third in Europe and among the first 30 countries in the world. As geologists, we are especially interested in groundwater. Rocks and sediments, which yield economically useful quantities of groundwater, are called aquifers. They represent storage space for significant amounts of water. Moreover, water stored underground is better protected from superficial negative impacts in comparison to surface water. It is therefore safer for human utilization and is often pumped for public water supply systems. Aside from that, should the layers containing water be at great depth, the water can become heated. Earth's interior produces large amounts of heat, which is constantly brought to the surface. This continuous heat flow creates a geothermal gradient – the temperature rises with increasing depth. Waters heated in this manner are called geothermal waters. Croatia abounds in geothermal as well as freshwater aquifers.

Two distinct regions

Croatia consists of two geologically very different regions. The north-eastern part of the country belongs to the European province of the Pannonian basin, and the water bodies there belong to the Danube River Basin. The aquifers are gravels and sands deposited by present day rivers, and thick sediments and sedimentary rocks left over from the fossil lake, Pannon. Rocks and sediments of the Pannonian basin can be up to six kilometres thick, so the waters that reside at depth are heated, as well as chemically altered. The south-western part of the country is a part of the Dinarides, a young European mountain chain. Dominant rocks in this part are limestones prone to karstification. In the fractures and conduits within them, vast reservoirs of freshwater exist. Although the waters circulate kilometres deep below the surface, they are not heated as in the Pannonian part, because the heat flow in this region is not significant. Water bodies in the Dinaridic region belong to the Adriatic Basin.

Wealth for water supply

As mentioned in the introduction, Croatia has abundant renewable water resources, around 25,000 m^3 per capita annually. To put it into context, the two European countries with more available water are Norway and Iceland. It is clear that the value of water is not the same in oceanic and boreal climates as it is in the sub-arid Mediterranean region and Pannonian basin with strong continental influences. Out of the total renewable water resources per inhabitant, the renewable groundwater resources account for 7,000 m^3 annually, or 28%. Groundwater is the dominant water resource in general, including water supply utilizations. Of the total number of water permits and concessions, 61% are given out for groundwater. That number is even more significant in the public water supply sector, where 88% of the water utilized is groundwater. The total renewable groundwater supplies in Croatia amount to 2.03*1010 m^3 annually. Looking at this by regions, the Pannonian has 16%, while the Dinaridic has 84% of renewable groundwater supplies. These fractions are very important, because they show that the majority of potable groundwater reserves are situated in the Mediterranean region of Croatia, while other European countries in that region face water shortages both currently and in the long-term forecasts.

The total extraction of groundwater comprises a low percentage of the total renewable resources: 4% in the Pannonian and 3% in the Dinaridic regions. However, in areas with higher population density, especially the capital Zagreb, extraction from the gravely alluvial aquifer reaches up to 70% of the renewable groundwater reserve.

Wellness and energy from groundwater

Geothermal aquifers are predominantly present in the Pannonian part of Croatia, which has favourable geothermal characteristics (see map in the figure – numbers represent water temperatures). Croatian geothermal localities can be subdivided into two categories: springs and deep boreholes. Springs are localities where geothermal water naturally flowed out or is still flowing out from the aquifer onto the surface. At some locations, natural springs have dried up following high pumping rates. The category of deep boreholes accounts for all the localities where there are not (nor were there ever any) natural springs, and geothermal waters were found during deep exploratory drilling for oil and gas.

Except by the mechanism that they come to the surface, geothermal waters also differ in their temperatures. The temperature range in which waters are currently being utilized is from 17 to 98 °C. Geothermal waters in Croatia have been categorized according to a modified balneological classification – into subthermal (13-20 °C), hypothermal (20-34 °C), homeothermal (34-38 °C) and hyperthermal (>38 °C). This was created based on traditional Croatian balneological classification from 1950s, which actually stemmed from considerations of German and Swiss medical balneology experts from the beginning of the 20th century. It is obvious that the point of reference for this scale is the average human body temperature, so homeothermal means the same as human temperature (from Greek homós, or 'the same'), hypothermal is below that temperature (Gr. hypó 'below') and hyperthermal is above body temperature (Gr. hypér 'above'). Modifications were made in the lower part of the scale because, in balneology, waters with temperatures of 20 °C and higher are being considered. From a hydrogeological point of view, however, all ground waters with temperatures higher than the mean annual temperature of the locality are considered geothermal, albeit they cannot be used in balneology.

The utilized waters considered in this overview range from subthermal to hyperthermal.

Croatia

The mode of utilization varies according to the temperature, e.g. waters at the lowest temperatures (17-20 °C) are used for fish farming, while waters at the highest temperatures (68-98 °C) are utilized for space heating and hot water preparation. In total, geothermal waters in Croatia are utilized in the following ten activities: recreation, balneotherapy, water heating, space heating, greenhouse heating, fish farming and directly as sanitary water, public water supplies and bottled table and mineral water. The most frequent modes of utilization are recreation and balneotherapy, which is the modus known from prehistoric times and antiquity. Those uses are followed by water and space heating, and the utilization of thermal water for sanitary purposes. Other modes of utilization are only present in one or two localities.

In St. Jana, there is a natural spring of hypothermal water (24 °C), but the investors decided to drill a borehole to reach warmer water for a recreation centre. In the end, the borehole was finished at a depth of 800 m, tapping the same aquifer and giving water of the same temperature. However, owing to its favourable calcium to magnesium ratio, excellent protection from pollution and marketing, it became very popular as bottled water. Although the investment was initially misplaced, in the end the borehole is making impressive revenue. There is also an example in the town of Križevci, where hypothermal water is cooled down and has been used for public water supplies for decades.

It can be stated that geothermal water utilization in Croatia is stagnating, rather than experiencing growth. At some localities where geothermal water is currently being utilized in a single mode, there are plans to increase pumping rates and introduce new modes of utilization, since there is a consensus that having more users and extracting as much heat as possible significantly increases the economic viability of geothermal projects.

Owing to a long history of geothermal water utilization in present-day Croatian territory, the researchers were devoted to their exploration. For example, the oldest chemical analyses date back to the last decades of the 18th century. In that period, mainly chemists and medical doctors were interested in the subject, due to applications in balneology. Comprehensive geological research started at the end of 19th century, but reached its peak during the 1970s oil crisis. At that time, the Federative Republic of Croatia (part of Yugoslavia at the time) established a fund dedicated to systematic thermal and mineral water exploration.

Groundwater giving names

A significant number of geothermal localities in Croatia are mirrored by the incidence of toponyms toplica/e, meaning hot water spring/s and topličica, meaning warm-water spring (the diminutive refers to the lower temperature of the water, not its quantity). Some of the localities were utilized even in prehistoric times, and in ancient Roman times, they were already established curative destinations, especially Aquae Iassae (Varaždinske toplice), Aquae Balissae (Daruvarske t.), Aquae Vivae (Krapinske t.), Aquae Vitae (unknown location), Ad fines (Topusko) where archaeological remains stand to this day. Not only thermal, but also mineral springs can be recognized through toponymy. Highly mineralized cold springs are recognized in toponyms like Slatina (literally salty spring) and Kiselica (sour spring with dissolved CO_2). They have also been utilized, for drinking and bottling, for centuries.

However, the most interesting story about geothermal springs comes from ancient history. Before the Roman Empire, a number of Illyrian tribes populated areas of present-day Croatia. One of the tribes specifically occupied the north-western part, with 25 natural warm and hot springs. They became known as Iassi all around the ancient world. Their name derives from Greek root –ias/-iatria meaning cure, because they were medicine men, using the healing powers of hot water. The same root is present today in the form iatros – physician (e.g. paediatrician, psychiatrist). This fact shows that even before the arrival of spa-loving Romans, geothermal springs had a specific place in the culture of this area.

Croatian
Geological Survey

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Staša Borović is a postdoctoral researcher at the Department of Hydrogeology and Engineering Geology of Croatian Geological Survey. Her primary interest is geothermal and she conducted interdisciplinary hydrothermal system research for her PhD thesis. Other interests include shallow geothermics, groundwater protection and transboundary groundwater issues.

Cyprus

Introduction

The chemical composition of natural mineral and alkaline spring waters is primarily a manifestation of the results of water-rock interaction. Precipitation (rainfall and snow), drawn by gravity, percolates downwards through the pores and fractures of the underlying rock to eventually reach groundwater and continue its flow. During this complex and long journey, adequate contact time is given for the water to interact with the hosting rock and shape its unique chemical composition by acquiring mineral salts, ions and trace elements along the way.

In Cyprus, these types of water are usually found in the ophiolite complex of Troodos, the dominant geo-topographic feature occupying most of the central part of the island. Due do the seasonality of most of the rivers in Troodos, springs were of upmost importance to the pioneers who settled down in close proximity to them, thus ensuring the constant supply of potable water during Cyprus' long, hot and dry summers, when most of the rivers dry up. Socioeconomic value was later added to areas where alkaline springs occur as they became areas of deity worship and hydro-therapy for the commons, aristocrats and kings.

Today, natural mineral and spring water is still used for water supply and irrigated agriculture, and in some cases is marketed by a number of companies. Furthermore, alkaline springs are also used, though to a lesser extent, for spas and hydrotherapy.

Why it is special and why it is good for our well-being?

The geological setting of an area and the prevailing lithology of the hosting rock are the controlling factors in the occurrence and chemical composition of natural mineral and alkaline waters. Groundwater percolation depth and flow path are usually controlled by the geological setting of the area. In the case of Cyprus, the Troodos ophiolite complex, where these types of waters mostly occur, was formed in the Upper Cretaceous (90 million years ago) on the Tethys sea floor, which at the time extended from the Pyrenees to the Himalayas. It is a fragment of a fully developed oceanic crust, consisting of plutonic, intrusive and volcanic rocks and chemical sediments. It was created during the complex process of sea-floor spreading and formation of oceanic crust and was emerged and placed in its present position through complicated tectonic processes related to the collision of the Eurasian plate to the north and the African plate to the south. The uplift of the island took place during episodes of abrupt uplift up to the Pleistocene (2 million years ago). The uplifting, twisting and erosion of the rocks has resulted to their intense fracturing, adding in the development of the Troodos aquifer with numerous seasonal and perennial springs.

Lithology and mineralogy are equally important parameters in the formation of mineral waters. Hosting rocks' primary and secondary minerals are dissolved by the percolating water, thus acquiring its mineral salts, ions and trace metals. In the case of Troodos, fractured gabbros (plutonic rocks) and diabase (intrusive rocks) are the predominant hosting rocks for groundwater and springs. The minerals olivine/pyroxene, plagioclase and (oxidized) sulphites are the main sources of magnesium sodium/calcium and sulfate salts, respectively. The former two are primary minerals in both hosting rocks and the latter is usually found disseminated, mostly in the diabase. The resulting bicarbonate mineral waters are commonly rich in magnesium and calcium, a composition extremely nutritional for humans and highly suitable for agriculture.

The longer the groundwater flow path (and consequently the rock-water contact time), the higher the salt concentration of the mineral water. Excessively prolonged water-rock contact time usually results in extreme salt concentration in the water. Alkaline springs in Troodos, high pH water with high sulfate salt concentrations, is such an example, and mirrors the interaction of groundwater with ultramafic rocks and serpentinites. Studies have also shown that in some cases the hydrochemistry of alkaline springs results from the mixing of ground-water with connate water and/or older hydrothermal fluids associated with the serpentinization (alteration) of the ultramafic rocks. Alkaline springs are thought to have beneficial effects on healing rheumatic and skin diseases as well as digestive disorders.

Use of the resource

The occurrence of good quality potable water in the semiarid environment of Cyprus was (and still is) of vital importance to the survival and wellbeing of the islands' inhabitants. Naturally, the occurrence of spring waters dictated the settlement of the early inhabitants, who have exploited these resources for drinking and irrigated agriculture. Even today, spring water in Troodos is used for water supply and agricultural needs, not only for the local, but in some cases for distant communities as well. Furthermore, more than 20 small and medium size companies are marketing more than 280.000 cubic meters of natural mineral and spring water per year from Troodos.. According to the Directive 2009/54/EC, natural mineral waters are characterized by their purity at the source, their constant level of minerals, and that they are microbiologically wholesome; characteristics which may give them properties favorable to human health. Mineral waters can be exploited from springs and boreholes and are subject to an authorization procedure carried out by the competent authorities of the European Union member states. Currently three such sources are certified in Troodos, and a number of others market natural spring water (under the provisions of the same directive).

Natural mineral water is valued so much basically because it contains a number of very valuable nutrients for the human body and they come without any calories. For example, almost all of the calcium in the human body, about 99%, is stored in our bones and skeleton, rendering it (along with magnesium) extremely important for healthy bones, teeth

and muscles. Furthermore, it is believed to have an impact in digestion, transmission of impulses through the nerves, energy metabolism and blood clotting. Magnesium triggers more than 300 enzymes, some of which are needed for energy metabolism and nervous system function. Bicarbonate helps neutralize the acids in our bodies and, in the form of sodium bicarbonate, it was found to reduce blood pressure.

A number of small local hotels still offer spa and hydrotherapy services through the use of alkaline springs. Nonetheless, they are mostly confined to the geographic area of Marathasa valley, where numerous alkaline springs with high sulfate concentrations occur.

Threats and protection

Natural mineral waters acquire their constant hydrochemistry and purity usually due to their deep and long flow paths, thus ageing before any pollution gets to them. Furthermore, protection zones are established around the borehole or spring in which potentially polluting human activities are restricted or regulated. Nonetheless, in a fractured aquifer environment, these measures may not necessarily always prove to be sufficient. Because of the complex and interconnected nature of Troodos' fractured aquifer, human activities such as drilling, over extraction, agriculture and urbanization, even outside the protection zones, may have a detrimental qualitative and/or quantitative effect on the resource. Despite the fact that when considered in unity, Troodos aquifer is not overexploited, there are areas of extensive groundwater extraction. This might be the greatest threat to natural mineral, springs and alkaline waters. On the other hand, the majority of the Troodos aquifer area is State forest, where human intervention is limited, thus posing almost no threat to groundwater resources.

Myths or stories

The occurrence of springs, especially in semi-arid areas of Cyprus, have often been linked to deities and myths. A very good example where ancient history, myths and religion intermingle with science is the case of the alkaline springs in the village of Kalopanayiotis, in the Marathasa valley of Troodos. These 11 springs are found along the banks of Setrachos river, next to a Venetian bridge. The whole area was part of the ancient Kingdom of Soli, whose kings used the area for their wellness resort and hunting outings. The spring waters' beneficial effects on healing skin and rheumatic diseases as well as digestive disorders were known since antiquity. It is thought that a temple dedicated to Asclepius, the ancient god of medicine, was located on the same exact spot where the Agios Ioannis (St John) Lampadistis Monastery stands today. As locals say, 'sulfate water' consumed in small quantities from the 'stomachiko' spring, which has relatively low concentration of sulfate salts, can be very beneficial to stomach problems. Furthermore, the locals used the water of the 'Psamiakos' spring, which has higher concentrations of sulfate salts than the 'stomachiko' spring, for spa therapy. For women, dissolved sulfate salts in the water can be a great way to naturally preserve and rejuvenate the skin.

Christos Christofi is a geological officer at the Hydrogeology Section of the Cyprus Geological Survey Department. He is a hydrogeologist working in groundwater exploration and protection with special interest in hydrochemistry.

Geological Survey Department of the Republic of Cyprus

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Czech Republic

Introduction

Concerning groundwater resources, the Czech Republic is among the richest countries in Europe owing to its geomorphological and geological position and beneficial climatic conditions. Due to the diverse geological structure and large number of rock types in the territory of the Czech Republic, various types of sources for high quality drinking and mineral waters can be found.

In particular, mineral waters represent deep interactions between rocks and water and they bear witness to the geological evolution of the area. Each of the many existing types of mineral and thermal water require specific geological conditions for its formation. Acidulous mineral waters, the most common type of mineral water in the Czech Republic, are bound to deep faults in the Earth's crust. These faults both supply juvenile carbon dioxide and, at the same time, are the source of the heat for thermal waters. Warmed up water or water enriched with carbon dioxide seeping through rocks dissolves them easily and absorbs some minerals, which causes an increase in the total dissolved solids content and creates its specific chemical composition. The occurrence of deep faults and other essential conditions are typical for geologically young or unstable areas.

Why it is special and why it is good for our well-being?

Mineral waters in the so-called Spa Triangle in West Bohemia, demarcated by Karlovy Vary (Carlsbad), Mariánské Lázně (Marienbad) and Františkovy Lázně (Franzensbad), are the most well known in all the Czech Republic. Many other resources for mineral waters are found in the wide surroundings of those spa resorts. Waters of this area are typified by high contents of sodium, sulphate, chloride and hydrogen carbonate, and the presence of carbon dioxide is common. Mostly they are cold, and thermal waters with temperatures up to 73°C are rare. In spite of some differences in their chemical composition or temperature, all these waters belong to one genetic type. However, each of the main spa resorts of the Spa Triangle is unique, specifically due to rather variable rock backgrounds and other geological and natural conditions.

Karlovy Vary is world famous for its curative hot springs, rising to the surface along faults in the granite massif, which go deep toward the Earth's mantle and create the high geothermal gradient in the area. All mineral springs in Karlovy Vary are of identical chemical composition, with very high total dissolved solids content and high carbon dioxide content. The major spring Vřídlo (meaning "hot spring"), with a water temperature of 73°C, sits at the crossing of two faults, representing the main ascent path for hot waters in Karlovy Vary. The geyser of Vřídlo, gushing to a height of 14 meters, is a unique natural phenomenon that has become the symbol of the spa. Other springs along the Karlovy Vary spring line are, in fact, branches of this major hot spring and their temperature goes down gradually, to 30°C.

Contrarily, in Mariánské Lázně, all mineral springs are cold and they are specified by significantly varied chemical composition within a relatively small area. All the mineral waters in Mariánské Lázně have their origin in one groundwater flow, which is formed by infiltrated rainfall in the surrounding highland. Water enriched with carbon dioxide circulates at a depth not exceeding 100 meters, but in distinct rock types. Major springs rise to the surface in a roughly 3 km long valley built by granites, diorites, gneisses and amphibolites, and these rocks support different mineral components. That is why mineral waters with various combinations of chemical compounds, with high total dissolved solids content, occur in Mariánské Lázně.

Františkovy Lázně offers a large number of mineral springs in a very close area. Their chemical composition is not as differing as in case of Mariánské Lázně's, though several hydrochemical types of water can still be found there. Františkovy Lázně is situated in the area of the strongest earthquakes and youngest volcanos in the Czech Republic. In this geologically active environment, mineral waters form and then accumulate in the overlying Neogene sediments. They are typified by very high contents of sulphate, caused by the presence of so-called Glauber's salt (sodium sulphate) and with very high total dissolved solids content (up to 20 grams per litre). This chemical composition in combination with presence of carbon dioxide is very rare.

It is natural, that drinking water of good quality is crucial for our healthy life and well-being. As for mineral waters, they are something special – a highly concentrated mixture of natural substances and, as such, they are not suitable for continuous consumption. They can be used for medical treatment as well as for relaxation and a wide scale of wellness procedures. Moreover, experiencing and tasting mineral waters and springs mediates contact with the power and variety of Earth and nature.

Use of the resource

Mineral waters in the Spa Triangle have been known for ages, and their healing effects have been proven by centuries of practical experience. Spa treatment kept changing, and nowadays there are many spa cures available to treat a wide variety of ailments. The basic therapy consists of the drinking cure to treat metabolic disorders, gastrointestinal diseases, disorders of the urinary tract, cardiovascular diseases, and others. Mineral baths and peat wraps help moderate locomotive system disorders and, at the same time, they support drinking cure's effects. Dry carbon dioxide is used for gas baths and other gas application to treat gynaecological disorders or cardiovascular diseases.

In addition to these medical treatments, spa resorts in West Bohemia can offer almost everything to follow the wellness philosophy, which works as a preventative against the negative influence of today's stressful world on human health.

Czech Republic

Threats and protection

The most important components, from the viewpoint of therapeutic use of mineral waters in Spa Triangle, have to be considered non-renewable in the human timeframe, because they originated in past geological periods. Simple collecting of mineral waters at springs in the past was replaced with drawing by boreholes that are much more efficient. Due to the pumping, the groundwater flow became faster and therefore washing of the non-renewable components out of the rocks became more intensive. In this way, excessive drawing would threaten not only the quantity of mineral water resources, but could irreversibly alter the chemical composition as well.

It is certainly no surprise that all spa resorts in West Bohemia have regulatory protection against pollution with defined protective zones for mineral waters. The protection against decrease of non-renewable chemical compounds is of the same importance, and is based on withdrawal of only the absolutely necessary amount of mineral waters. For this purpose, some of the boreholes are equipped with automatic monitoring systems to not exceed the permitted volume of pumped mineral water.

Myths or stories

The use of Karlovy Vary mineral waters has an ancient tradition. According to legend, it was discovered in 1350 by Emperor Charles IV, hunting in the deep forests of this region, after one of his dogs had fallen into a pool with nearly boiling water. Charles concluded that the hot water had some healing effects and bathed his sore legs in it. Twenty years later, Charles IV granted royal town privileges to the already existing spa, Karlovy Vary.

Hot mineral waters were used only for baths until the 16th century, since they were believed to wash pathogenic germs out of the skin. Baths prolonged up to ten hours were applied, which often led to painful skin chapping. Drinking cures found their use gradually, and soon another extreme came, a consumption of 70 cups of mineral water per day by one patient.

In the 18th century, physician David Becher was working in Karlovy Vary. He had modernized the therapeutic treatments significantly. For instance, he propagated drinking mineral waters outdoors at the springs and recommended walks as a part of the therapy. It resulted in the building of pavilions, colonnades and parks and, as an upshot, it changed the whole spa way of life. Numbers of spa guests, including prominent personalities of political and cultural life, were increasing rapidly, and Karlovy Vary became the world's most well-known spa resort.

Another member of the Becher family, pharmacist Josef Vitus Becher, began production of a famous herbal gastric liquor, Becherovka, sometimes called the tastiest spring in Karlovy Vary.

Czech
Geological Survey

Eva Kryštofová is a hydrogeologist in the Czech Geological Survey, specializing in hard rock and regional hydrogeology and field hydrogeological research. She is a member of the Czech Hydrogeologists' Association (ČAH).

Denmark

Introduction

Practically 100 % of the Danish drinking water supply is produced from groundwater typically extracted at depths of between 10 to 50 meters below ground but water supply and irrigation wells exist down to more than 200m depth, especially in the Western part of Denmark. The main aquifers containing and providing groundwater in Denmark are Quaternary sands deposited by the glaciers during the last ice age, fluvial and marine sands deposited by rivers and the sea during the Miocene and marine limestone and Chalk deposited in the sea during the Cretaceous – the last geological period in which dinosaurs walked the Earth and swam in the sea.

Groundwater abstraction from drilled wells for drinking water supply increased in the last part of the 19th century. Copenhagen experienced a Cholera epidemic in 1853 with nearly 5000 people dying of Cholera, and after the epidemic a large effort was initiated to ensure better and healthy drinking water for the public.

Geologists Prof. J.G. Forchammer and his assistant J.F. Johnstrup – who later became the first director of the Geological Survey of Denmark in 1888 – along with the Copenhagen Municipality had at the time already explored areas around Copenhagen for groundwater resources suitable for drinking water supply for about a decade. They knew that the existing water supply primarily from surface waters was of poor quality and that groundwater resources had many benefits compared to the surface waters.

In addition, the founder of the Carlsberg Breweries, J.C. Jacobsen, had also realised the importance of high quality waters for the production of beer and following the advice of Prof. Forchhammer and others, he started to explore for groundwater resources in Valby, Copenhagen, in order to ensure a constant high quality of water for the brewery. In 1855 the first two wells were developed to a depth of about 20 meters. In the late 1860's the two original wells were not supplying enough water and in 1869 a new one was drilled to a depth of 34 meters in between the two first wells. The three wells operated without problems until the end of the century where saltwater intrusion started to affect the water quality. At that time the brewery had to give up using the extracted groundwater for beer and could only use it for the production of soft drinks. Later other wells were drilled in the area, but in 1970 the Carlsberg breweries gave up their own wells and has since received all its production waters from the Copenhagen Water Supply Company (HOFOR) abstracting groundwater from a large area around Copenhagen.

Since these pioneering groundwater exploration activities in and around Copenhagen during the last part of the 19th century, the amount of the drinking water sourced from groundwater has been steadily increasing to the present day figure of 100%.

In the 1920s it became clear that a sound understanding and management of the groundwater resources (e.g. protection of the resources) was of crucial importance and hence in 1926 the first water supply act based on groundwater resources protection in Denmark and possibly the world was adopted.

Why it is special and why it is good for our well-being?

As was described in the introduction, groundwater has been known for a long time to have beneficial properties and be pure. Groundwater flowing through the aquifers dissolves minerals from the rocks and it is filtered through the passage between the grains of the rocks and sediments in the subsurface. By this process practically all pathogens are removed from the water and typically very little treatment is needed before the water can be consumed. The dissolved minerals, however, may or may not be healthy and strict quality control is always needed if waters are consumed on a daily basis.

Groundwater has other uses than drinking water. In Denmark hypersaline groundwater was extracted since medieval times from shallow aquifers at depths of less than five meters on Southern Laesoe, a small Island in the Northern part of Denmark. The hypersaline groundwater was not used for drinking water as it was much too salty, but to produce salt primarily to conserve food. Hence, the groundwater itself did not ensure the well-being of people in the Middle Ages, but the salt produced from the hypersaline groundwater helped to conserve food and hence ensure the health of people by keeping the food in a good condition. The salt was produced by the salt seething process in a large number of cabins (perhaps up to 2000) on the island. Salt making by seething was stopped on the island of Laesoe by a royal decree in the 16th century because the salt making had cleared Laesoe of all forests. However, salt making by seething was reconstructed on Laesoe in 1991 in a combined archaeological research and municipal employment project. Since then large amounts have been produced and sold within Scandinavia for the Nordic Gourmet Kitchen, which is just another way to ensure the health of people.

This is however not the only way that the shallow hypersaline groundwater of Laesoe ensures the health of people. Since 2008 the hypersaline groundwater is used for the treatment of people with the skin disease psoriasis in an old rebuilt church on the island. It was shown that the Psoriasis Area Severity Index (PASI) often was improved by 80 % after treatment with the hypersaline groundwaters of Laesoe.

Use of the resource

The groundwater resources in Denmark are used not only for drinking water, but also for food production (e.g. by irrigation of farmlands and by industry). However, in contrast to the main belief, the abstraction of groundwater has been declining due to increased water pricing and better maintenance of the water distribution systems for some decades. Over abstraction still occurs though around major cities, and in coastal areas where declining water tables can suffer from low in-stream flows and salt water intrusion.

Denmark

Threats and protection

The groundwater quantity and quality is threatened in many parts of Denmark, not least as about 2/3 of Denmark is covered by intensive agriculture. Agricultural practices leak nutrients, pesticides and other pollutants that threatens both groundwater as a drinking water resource and human health, but also groundwater dependent terrestrial and associated aquatic ecosystems. Other threats occur from households and industry and efforts are continuously made to monitor the evolution of the groundwater quantity and quality. Groundwater monitoring results are accessible through the website of the Geological Survey of Denmark and Greenland, and data here shows that efforts made during the past 30 years in different water and environment action plans to protect groundwater quality are working and that the groundwater quality in Denmark is slowly improving. Assessments of the groundwater chemical status according to the Water Framework and Groundwater Directives, however, show that the Danish groundwater in many areas will not comply with the good status objectives in the near future.

Myths or stories

During Medieval times the hypersaline groundwaters on the island of Laesoe were identified by digging shallow wells on the shore. If a hen's egg could float on top of the water the groundwater was suitable for salt production. An egg floats when the salt content is 12%, or nearly four times the salinity of seawater.

Geological Survey
of Denmark and Greenland

Klaus Hinsby is a research hydrogeologist at the Geological Survey of Denmark and Greenland, his main research interests are groundwater chemistry, residence times and flow, and assessment of groundwater chemical status according to the EU Water Framework and Groundwater Directives. He is currently the chair of the Water Resources Expert Group of the EuroGeoSurveys, and the Danish Chapter of the International Association of Hydrogeologists.

Jens Morten Hansen is retired director general for the Danish Research Agency and Research Councils. He has had a carrier as center leader of the Danish Groundwater Group, vice-managing director of The Geological Survey of Denmark and Greenland and is now working with sea level changes.

Emilia Romagna (Italy)

Introduction

In common with much of Italy, Emilia-Romagna region has an abundance of naturally mineralised groundwater. This natural resource can be classified as belonging to one of two categories: mineralised waters which rise "naturally" to the surface and have long been known and used only locally; waters classified as "mineral" or "thermal" (these two terms are often confused), which are granted in concession and used by thermal spa establishments.

In accordance with a 1927 Italian law, waters classified as mineral or thermal are regarded as mineral resources. This is indicative of the considerable economic value then attributed to thermal springs, in a historical period known as "autarky" during the Fascist dictatorship, which exasperated the use of natural resources of national provenance.

It is no coincidence, therefore, that in Emilia-Romagna the period from 1930 to 1939 saw the granting of many of the mining claims with thermal water wells still operating today.

One of the oldest mining claims, meanwhile, is that of Salsomaggiore (Parma Apennines), which dates back to 1893, during the so-called "Belle Epoque".

Why it is special and why it is good for our well-being ?

It might seem paradoxical, but the key characteristic of the waters classified as thermal in Emilia-Romagna is that they are mostly "cold", with temperatures which rarely naturally exceed 20°C. The exceptions to the rule are Porretta (in the Bologna Apennines, water between 20 and 35°C) and Bagno di Romagna (in the Forlì Apennines, with a water temperature above 40°C).

A third case of groundwater with a recorded temperature of 38°C is that of Miano (Parma Apennines), relating to a 1040 metre-deep well for oil drilling.

As regards the chemical composition, the majority of thermal water wells yeld : salt-bromine-iodine water, from fossil water "trapped" inside sediments of ancient marine origin and released by formations derived from their lithification; sulphurous water, associated with the chemical reduction of sulphates, e.g. somewhere deriving from the dissolution of gypsum formations.

These two types of water are often found in the same concession area, originating from geologically different aquifers (sulphurous waters are often to be found in shallower aquifers, salt-bromine-iodine waters in deeper ones).

Ferruginous waters (also called "chalybeate", in italian "marziali") are much rarer.

A particular instance is the hot springs of Bagno di Romagna (Forlì Apennines), with deep bicarbonate-alkaline-sulphurous water that can be attributed to the mixing of deep seated groundwater with shallower ones, of meteoric origin .

From a general point of view, thermal spring waters are used for drinking (to cure digestive system disorders), inhaling (respiratory system diseases), bathing and the production of therapeutic mud (osteo-articular diseases, skin diseases) and in general for all treatments aimed at decongesting the mucous membranes. A number of curative uses are steeped in tradition, for example gynaecological conditions in particular have long been treated at the thermal spa of Porretta (the "Donzelle", or «Damsels» spring is especially renowned and in the Middle Ages it supplied an ancient bath that was reserved for women only).
In more recent times, thermal springs have been used in sports medicine and in the beauty and wellbeing sector. For this latter use, the more dynamic companies managing thermal establishments, have equipped them with separate SPAS for daily or weekend visitors, cuupled with the production of cosmetics formulated with thermal water.

Groundwater which is classified as "mineral "is used for bottling and no longer viewed as curative, but widely considered as drinking water. This is a natural resource which has the same geological origin as the groundwater used for public drinking water supply, since the mining grant areas are located within permeable hydrogeological complexes where aquifers occur; in Emilia-Romagna Apennines, aquifers provide water with medium to low mineral content.

The region has only a few "mixed" concessions, where in the same area wells exploiting different aquifers provide water used for thermal spa purposes and for bottling: examples of mixed concessions include the one named "S. Andrea" (Parma Apennines) and the springs at Cervarezza (Reggio Emilia Apennines).

Water resource distribution

In the study area, the majority of mineral and thermal spa water concessions are located within the Emilia Romagna Apennines.

There are 48 areas in all, corresponding to single or grouped mining claims, for a total of at least 63 "titles" which are currently active, from an administrative point of view.

The provinces with the highest number of concessions are Parma and Forlì-Cesena.

The Piacenza area boasts the historical thermal spa concessions of "Bagni di Bacedasco" and "Rio dell'Acqua Puzza". Parma province features major thermal spa "centres": Salsomaggiore, Tabiano, Monticelli and S.Andrea, plus around a dozen mineral water concessions.

The province of Reggio Emilia is home to the "S. Lucia" mineral water concession, with the thermal spa establishment of Cervarezza.

The province of Modena has a single thermal spa concession, the Salvarola establishment, along with numerous mineral water concessions.

Emilia Romagna (Italy)

The province of Bologna has two historical thermal spa major centres, Porretta and Castel S.Pietro, plus one mineral water concession in the municipality of Vergato.

Ravenna province is home to the thermal spas of Brisighella, Riolo and Cervia, the latter utilising the water of the local, artificial salt lagoons.

Forlì province has the thermal spa "centres" of Castrocaro (the largest concession operating in the region), Bagno di Romagna and Fratta, in addition to several mineral water concessions.

In the Rimini area, thermal spa establishments include the historical concessions of "Castellabate" and "S. Francesco", in addition to the better-known Riccione spa.

Essentially, thermal waters are found in a relatively constant geological setting, attributable to deep formations containing water with particular mineral content, benefiting from the natural "protection" of overlying clayey units, with mineralised water rising to the surface through fault systems.

Threats and protection

In spite of the widespread and qualified touristic offer of our region, the thermal spa industry in Emilia-Romagna is locally at risk, not so much from geological-environmental factors, but from the reduction of people attending watering places.

This already gloomy picture is compounded by the current economic crisis but, at local extent, it also reflects a lack of investment aimed at updating spas, coping with new market demands.

As regards mineral water, it is essential that abstraction from wells does not spoil the natural availability of water, which is also used by local water supply networks.

Myths or stories

Historically, in addition to its use in medicine, thermal water was also used for veterinary purposes and in the food industry, for its salt, the latter practice re-introduced locally during the Second World War. As documented in the book "Spas and secret waters of Emilia-Romagna" (Rosetti and Valenti, 2002) some thermal waters have been renowned since Roman times or indeed earlier (Salsomaggiore, Porretta, Salvarola, Riolo Terme, Castrocaro, Fratta, Panighina, Bagno di Romagna, Galvanina). A number of spas enjoyed considerable popularity throughout the Medieval and Renaissance ages: one of them is Porretta, mentioned in the play "Mandragola" by the Florentine humanist Niccolò Machiavelli.

In the 19th century, scientists began to study thermal waters from the perspective of modern chemistry and medicine. Among others, the thermal spa establishments of Porretta, Salsomaggiore and Castrocaro became "Villes d'Eaux", attracting the cream of fashionable society.

There are a number of spas which, despite being ancient and renowned since Roman times, are now totally abandoned: Lesignano Bagni (Parma Apennines), Quara (Reggio Emilia Apennines) and Bobbio (Piacenza Apennines).

A mining grant for prospecting the historically famous cold saline springs called "Fonti di Poiano" (Reggio Emilia Apennines), has now expired.

Servizio Geologico sismico e dei suoli

Maria Teresa De Nardo, born in 1963, is a geologist. She works in the Geological, Seismic and Soil Survey of the Emilia-Romagna Region. In the Nineties she practiced field surveying and geological mapping for the CARG Project (Geological map of Italy to scale 1:50,000), then she was committed with the study of groundwater and natural resources in the Emilia-Romagna Apennines.

Estonia

Introduction

Estonia is a country in the Baltic region of Northern Europe. It is bordered to the north by the Gulf of Finland, to the west by the Baltic Sea, to the south by Latvia , and to the east by Lake Peipus and Russia. Average elevation reaches only 50 metres. There are 3,794 kilometres of coastline marked by numerous bays, straits, and inlets. In Estonia, the mires cover 5.6% of the territory and 61% of territory is covered by forests. The country has large oil, shale and limestone deposits.

The first geological studies were carried out in Estonia more than 150 years ago. In Estonia, the shallow groundwater flow systems can be distinguished from deep groundwater flow systems; the former interact with surface water, while the latter do not. The whole infiltration of water percolates into the Quaternary cover and the greater part of groundwater discharge flows through it. The terrigeneous and carbonate Palaeozoic and Proterozoic rocks form porous, fissured and karstified, mostly confined aquifers, which are isolated from each other with aquitards of different isolation capacity. The deep Cambrian–Vendian aquifer system lies at the depth of 80–100 m in the northern part of Estonia and increases to 600 m in South Estonia. These deep aquifers contain pre-Quaternary groundwater, which is high in total dissolved solids (TDS) and moves very slowly under natural conditions.

Why it is special and why it is good for our health

Groundwater forms about 70% of consumed drinking water in Estonia. Tallinn and Narva are the only towns where the consumption of purified surface water exceeds that of groundwater, while elsewhere in Estonia groundwater is the only source of public water supply. The urban water companies deliver water to households, institutions, commerce and small-scale industry located within the urban areas. The major amount of groundwater is extracted from wells with depth up to 50 m, which usually consist pure groundwater.

The centralized water supply of the bigger towns in north-eastern Estonia is mostly based on groundwater consumption from the Cambrian–Vendian aquifer system. In coastal areas it is the only source of water supply available. Along the northern coastline, the Cambrian–Vendian aquifer system lies at a depth of more than 80 m and is practically protected from contamination due to effectively confining Cambrian clays. The aquifer system comprises two independent aquifers, the Voronka and Gdov aquifer (groundwater bodies), which are isolated from each other by the Kotlin regional aquitard, with a thickness of 15–30 m.

The chemical composition of these aquifers is extremely unique, not only in Estonia but worldwide. In the genesis of groundwater, the ancient sea-water component may play an important role. In northern Estonia Cambrian–Vendian aquifer system contains a typical glaciogenic palaeowater that in some places may have mixed with infiltration water. The concentration of chlorides is usually 100–200 mg/l. Only around the deep buried valleys, which were formed under the ice and discharge of meltwater during latest glacial period, is the content of Cl less than 50 mg/l.

Another type of groundwater is represented in southern Estonia, where groundwater contains more than 350 mg Cl/l. The accepted limit of chlorides in drinking water is 250 mg/l. The salinity of relict Na-Cl type groundwater in South Estonia is 2–20 g/l and rated as mineral water. In comparison with ordinary spring water, natural mineral water is rich in several beneficial minerals like calcium, potassium, magnesium and sodium that support vital functions of the human organs and nervous system.

Use of the resource

The Cambrian–Vendian aquifer system occurs almost all over Estonia. The water-yielding portion consists of sandstones and siltstones with interlayers of clay. In northern Estonia, the aquifer system is confined by 60–90 m thick clays of the Lontova Formation.

About 123 thousand m^3/d of groundwater is abstracted in Estonia for domestic use. From this amount, an average 28% is extracted from the deep confined Cambrian–Vendian aquifers. The aquifer system crops out in the Gulf of Finland not very far from the shoreline. The resources of fresh groundwater in the Cambrian–Vendian aquifer system are limited and consist mainly of natural reserves formed during the Pleistocene glaciation.

Due to intensive groundwater extraction in northern Estonia, two extensive drawdown cones have formed with centers located in Tallinn and Kohtla-Järve, where the potentiometric levels of Cambrian–Vendian aquifer system 25 years ago were lowered to 30 m and 50 m below sea-level respectively. The groundwater abstraction in Tallinn was high (more than 40 000 m^3 per day) up until 1991. Since this time, due to water savings in response to the introduction of metering and market pricing of water, the groundwater abstraction declined abruptly. The fall in potentiometric level up to 1990 indicates that previous abstractions exceeded the recharge of the aquifer within the abstraction area. Since 1990, the recovery of the groundwater's quantitative and chemical status has been observed.

The first mineral water deposit in deep aquifers was discovered in 1959. Afterwards, mineral water was found in 16 different sites all over Estonia. The first special mineral water well was drilled in Värska in 1967. Mineral water is good for cooking with, used to dilute drinks, make sauces and soups, and even prepare baby food. It is good to know that slightly saline water is the ideal beverage when the body is perspiring heavily, as it restores the salt lost through sweating. Drinking mineral water helps compensate for the fluids and mineral salts lost in perspiration.

Estonia

Threats and protection

The most serious consequences of the intensive groundwater use include the formation of regional depressions of potentiometric level, which has caused changes in the direction and velocity of filtration flows in the Cambrian–Vendian groundwater system. As the groundwater body crops out in the Baltic Sea, not very far from the shoreline, the drawdown contours show that there exists the risk of recent seawater intrusion. Due to the intensive groundwater extraction, extensive drawdown cones have formed. The potentiometric levels of the Cambrian–Vendian aquifer system 25 years ago were lowered to 50 m below sea-level. In some places, the groundwater has high contents of chloride and other dissolved salts, which affect use for domestic water supply.

Monitoring of long-term variations of chloride and other characteristic components of sea-water between the coast and the main water intakes should be continued. The risk of saltwater intrusion into groundwater intakes will disappear only after ascending the potentiometric levels of operational wells above sea-level, which requires continuous decrease of groundwater consumption from deep aquifers in the coastal areas.

Natural mineral water is clean because it originates from the depths of the earth and flows in a protected and untouched environment.

Myths or stories

According to an old legend, Värska mineral water has miraculous powers. The bereaved widow Maarja was weeping by holy springs. The tears of pure love instilled power in the water rising to the surface from the depths of the earth. The thirsty can draw health, strength and long life from Värska water. There's always a grain of truth in folklore. Värska mineral waters contain beneficial elements that have a favourable effect on the entire body. The area around Värska has more long-lived people than anywhere else in Estonia.

Geological Survey of Estonia

Rein Perens is the adviser of hydrogeological department in the Geological Survey of Estonia. He is graduated from Tartu University with an MSc in applied hydrogeology and specialized in hydrogeological mapping and groundwater monitoring. He is member of the working group of the Estonian–Russian Transboundary Water Commission.

Finland

Introduction

Vast reserves of meteoric groundwater lie in Finland's superficial deposits. There are an estimated 10–15 billion cubic metres of groundwater stored in quaternary aquifers that are suitable for use as water supplies. The daily groundwater recharge is some 5.4 million cubic meters in the mapped and classified groundwater areas alone, only ten per cent or so of which is used by households. Hence, the majority of forming groundwater is stored, and any excess drains into surface waters.

High quality groundwater is stored in glaciofluvial eskers and marginal ice formations that were formed some 10,000–13,000 years ago by glacial meltwaters at the end of the Weichselian glaciation.

Groundwater is also stored in fractured zones of crystalline bedrock and in glacial till and moraine formations. Wells in these formations are usually so low-yielding that they are suitable only for small-scale water supplies.

There are over 6,000 classified groundwater areas in Finland. Their combined area is almost 5% of Finland's land area. Finnish public water supply is mainly based on these groundwater reserves. Groundwater areas and resources are not distributed evenly, however. In coastal urban areas, water consumption is significantly higher than the recharge in rather scarce aquifers, and hence in places like the Helsinki metropolitan area, surface water is the main water source.

Why it is special and why it is good for our health

The quality of Finnish meteoric groundwater is mostly good or excellent, and often even untreated water is potable. Pure water supplies are the base for clean, high quality food production, among other things.

Humans have long understood the benefits of clean water for well-being. Finns became interested in medicinal waters in the late 17th century. In the next century, water from dozens, if not hundreds, of commercial and free 'well resort' (terveyslähde) springs were used.

Spa culture flourished throughout the 19th century and in the early 1900s. Spas were built around the springs and well resorts and the waters were believed to remedy just about any ailment. The most prominent treatment was the internal use of water.

In Finland, natural spring water and artificial mineral water has been bottled for some two hundred years. Finland is completely self-sufficient in terms of groundwater and has a lot of capacity for exports.

Groundwater in glaciofluvial formations is naturally mildly acidic and very soft due to its low concentration of salts. Water-rock interaction time is longer in bedrock fractures than in quaternary sediments, and hence the salt content and pH value of water in bedrock aquifers is slightly higher.

In Finland, groundwater recharge is highest during autumn rains and the snowmelt in spring time. In wintertime, the groundwater tables tend to descend. Less groundwater is recharged in the summer due to increased evaporation and plants using water for their growth.

Due to seasonal changes, temperature in the upper part of groundwater body may vary by several degrees, but within 10–15 metres depth it will settle at 4–6 °C on average. The temperature of groundwater in bedrock is approximately 7–8 °C at 100 metres depth.

Threats and protection

The groundwater in inland aquifers in particular often meets the domestic water quality criteria as-is. However, as groundwater is typically mildly acidic, it is common practice to alkalise it prior to distribution. This prevents corrosion in the water distribution infrastructure. Usually, waterworks also disinfect the water, just to be on the safe side.

In low-lying coastal areas, in aquifers covered with clay and peat, the groundwater is generally low in oxygen or entirely anoxic, and may contain high concentrations of solute iron and/or manganese. These quality deficiencies can be relatively easily corrected by modern potable water treatment technology. Groundwater in certain local areas may also contain excessive concentrations of geogenic arsenic, fluoride, or radon. Waterworks will use, as necessary, natural and/or chemical methods to process the groundwater prior to distribution.

The primary aquifers, glaciofluvial formations, are also used as roads and construction areas, which causes a conflict and risk between water supply and other land use. The risk is slightly reduced by the fact that, despite our rich reserves of groundwater, individual aquifers tend to be rather small. The average area of all classified groundwater areas is just 2.5 km^2. For this reason, groundwater contamination may not spread far even when a single aquifer is badly compromised.

To reduce risks, groundwater is protected by strict regulation of the land use and groundwater exploitation in groundwater areas. National regulations categorically prohibit the alteration and pollution of groundwater. Protected areas have been set up around the majority of water pumping plants, either by legislation or as a guideline. Permits are required for water management projects that may alter the quality or quantity of groundwater. The regulations apply to businesses, associations, and individual citizens alike. Construction, gravel extraction, and other risk activities are limited when necessary. From 2000 onward, Finnish national legislation has also implemented the EU Water Framework Directive.

Research has been conducted in Finland to estimate the impact of climate change on groundwater conditions. In some scenarios, the increased rainfall and higher temperatures may cause the groundwater tables to rise above normal levels even in wintertime. The interaction of surface water and groundwater may change and impact the quality and quantity of groundwater. However, more verdant plant life and increased evaporation, combined with a prolonged growing season, may reduce the recharge of groundwater.

Finland

The 40-50 cm thick podzol layer, accumulated after the last ice age, acts as a refinery for the waters soaked/infiltrated into the ground. In case the level of groundwater table is permanently raised, the podzol horizon and suspension zones will not be able to retain the water seeping into the aquifer for as long. This may result in lower quality groundwater. Also, more frequent rains and the quicker melting of snow combined with high groundwater levels may increase the year-round risk of flooding.

In Finland, the environmental authorities are responsible for the protection, management, and monitoring of groundwater reserves. Waterworks are responsible for providing consumers with potable water with maximum reliability. The Geological Survey of Finland (GTK), universities, and consultancy firms specialising in the industry conduct groundwater research.

Groundwater is a significant source of raw water in Finland due to its high quality, little or no need for treatment and low contamination risk. By researching the conditions and changes in the recharge and storage of groundwater, we can ensure that groundwater can be utilized in a sustainable and safe manner in the future too.

Myths or stories

Water, being essential for life, has many beliefs and myths surrounding it. In Finnish mythology, vedenväki ('water folk') were underwater beings that possessed magical powers. Water spirits, water nymphs, and other water folk were said to dwell in lakes, rivers, rapids, the sea and even springs and wells.

Several spells related to springs exist in old Finnish folklore. Folklore commonly depicts spring-dwelling spirits as dainty young maidens. Springs and wells, or more often lakes and rivers, could also be inhabited by a malevolent spirit, näkki, who would drown people. Näkki and other similar mythical creatures (nixes) have been used as a deterrent for children to keep them away from deep waters.

Water and well spirits would guard the purity of the water by taking the form of people or animals. The spirits inflicted sickness upon those who would spoil or defile a well or spring. Angry spirits might also relocate a spring if dirty laundry, feet or dishes were washed in its waters. Those facing the wrath of a spirit could seek to placate them with offerings.

Water folk were used to heal the sick and even the mentally ill. As the saying goes: vesi vanhin voitehista ('water is the oldest ointment').

Vesisuoni ('water vein'), still in use in modern Finnish, comes from folklore and means a subterranean channel, generally an underground brook or pipe, that groundwater flows through. In reality, Finnish groundwater rarely if ever creates these veins. Folklore also tells of diviners (kaivonkatsoja), who would use an instrument such as a twig, pocket watch or ring to locate veins that could be used for wells.

Geological Survey of Finland

GTK

Birgitta Backman, Ph.D., works as a senior scientist at Geological Survey of Finland. She specialises in the geochemistry of groundwater and soil research. Her doctoral thesis in 2004 was on the factors affecting the quality of groundwater.

Miikka Paalijärvi, M.Sc. in Quaternary Geology, is a geologist specialising in hydrogeology and aggregate and rock material research. He has been employed at Geological Survey of Finland for 15 years, and for the last three has acted as Division Manager.

France

Introduction

Hot thermal waters and cold mineral waters are a representation of deep interactions between water and rock, with a loop depth of several kilometers. Raw materials for spa therapy and bottled mineral water, their nature is inextricably bound with the geological history of the area. From the rainwater to its resurgence as thermal or mineral water, water experiences a complex path, often mysterious, descending deep between geological layers, reaching high temperatures, making their way along faults, and rising to the surface. As water percolates deeper, it dissolves and absorbs some of the minerals from the rock. This is the primary cause of the high salinity found in these waters, resulting from a long path, usually over 10,000 years.

From the very first age of humanity, hot waters have been used by humans for treatment as indicated by the most ancient period of history. Thermal Spa, i.e. the use of hot water for medical purposes, dates back in France to 3000 BC. Thermal and mineral waters have been known for centuries, thanks to their particular smell, specific taste, various temperatures and supposed therapeutic effects. In France, thermal and mineral waters have been, since ancient times, various anchor points of human activity. Such anchoring is of a very specific geology, that of ancient geological reliefs, from the Vosges through the Alps and the Massif Central to the Pyrenees.

Why it is special and why it is good for our well-being ?

The role of geology in the genesis of thermal and mineral waters is crucial. These waters contain various mineral salts and gases, but many of them also contain trace elements that are thought to have properties favorable to health, with therapeutic value. In France, each of our spa resorts was consecrated by history. Celts, Gauls, and Romans have successively used the salutary powers of these waters. But, it is with the Roman occupation that construction of 'Thermes' multiply throughout Gaul. After a long period of neglect during the Middle Ages, hydrotherapy revived again in the sixteenth century. Under the impulse of Henry IV, the first charter for mineral waters was inaugurated in 1604. Over centuries and wars, spas modernized to accommodate the soldiers who come to heal their wounds. Under the Second Empire, with the advent of the railway, the spa resorts multiplied. Under the Third Republic (1870-1940), the techniques for the resource's exploitation became clearer, and therapeutic specializations were affirmed. The spa resorts welcome in their palaces brilliant society, including many foreigners, attracted by the cultural life of thermal cities as much as by their medical reputation. After the Second World War, spa therapy, hitherto reserved for the privileged, opens to the majority, with the consideration of the Social Security system.

Classical spa therapy advocates bathing in and drinking mineral waters as a cure for a variety of diseases. Throughout the 19th and much of the 20th centuries, medical doctors endorsed the health benefits of 'taking the waters'. In France, the medical approach of thermal waters is related to the physicochemical properties of water to specifically treat ailments of people taking health cures (respiratory diseases, rheumatology, trauma, neurological diseases, skin and mucosa diseases, phlebology, metabolic and arterial diseases). The therapeutic properties of thermal water are recognized by the Academy of Medicine and, as such, thermal water differs from area banal groundwater. The medical therapy uses mineral waters, steam, gases and hot mud, according to a variety of means of application. Nowadays in France, it concerns half a million patients who benefit yearly from a course of treatment at a spa resort. This spa heritage is limited to geological settings that allow the acquisition of the mineralization required to treat a particular condition. The thermal and mineral waters are used not only for drinking water and medicinal purposes but also for general wellness. For example, in our modern society, spa therapy is not simply to make use of a particular composition of water, steam, gas or muds, but also the opportunity to temporarily change one's lifestyle or climate. It is also taking care of his body, breaking the rhythm of daily life, to end up in harmony with oneself. Now, many authorities believe that the success of hydrotherapy really results from the beneficial effects of rest and relaxation. But on the other hand, it is worth noting that the French Association for hydrotherapy research, which aims to promote scientific research applied to the activity of spas, promotes clinical research to assess, particularly, benefits provided by hydrotherapy medicine. Medical and relaxation approaches are thus well mixed in France.

Use of the resource

Mineral water is a microbiologically safe natural water derived from a groundwater exploited from natural springs or by boreholes. This water must show stability in its chemical composition and temperature. It is not just the constant chemical composition that clearly defines a mineral water as for use in spas or bottling. Water should be endowed with certain beneficial properties to health recognized by the National Academy of Medicine to qualify as natural mineral water. But many waters, more or less rich in minerals, are not classified as mineral water, either. Naturally, due to the presence of mineral salts in amounts that exceed standards, a lot of mineral water is not drinkable. They are defined actually in the current supply to the public as drugs or therapeutic, as recognized by the Academy of Medicine. They can overcome various standards for dissolved salts, to the point of not having to be consumed exclusively and sustainably as drinking water.

Clinical tests must have demonstrated that the mineral water is good for health and contributes to the prevention of certain complaints, but mineral waters do not treat similar diseases; some treat urinary stones and rheumatism, others excess weight or digestive diseases and rheumatism. Highly mineralized waters are of interest to many people when intake of minerals and trace elements is insufficient. For example, this is the case for calcium, magnesium and fluorine. Calcium plays a fundamental role in growth and bone strength. Thus, calcium-rich mineral water can play an important role in our diet that should be rich in calcium, in addition to dairy products. Magnesium, among its numerous functions,

contributes to good neuromuscular relaxation and thus the overall well-being. Vegetables, dried fruit and chocolate are rich, but it is wise to strengthen these occasionally insufficient food intakes by consuming Mg-rich mineral water. Fluoride, mainly found in fluoridated mineral waters, promotes bone and tooth growth.

Threats and protection

Natural mineral water is defined as a protected groundwater due to specific geological conditions favoring long-time paths. If this deep circulation protects mineral waters from pollution, they are not free of problems. The danger is the emergence of the source, because they are often close to urban areas. Thus, some mineral waters have regulatory protection derived from the Public Health Code and based on the public statement that allows establishing a protection perimeter in which the requirements are in force. This is, first of all, to limit activities that make the natural protection less effective. Drilling and some underground structures may be subject to official authorization, limiting disruptions of the geological layers playing this protective role.

The sustainability of spa resorts can be threatened by lack of maintenance of the collection structures such as springs, boreholes or galleries. These structures may be damaged by collapses, corroded by the acidic nature of the water, or even plugged by concretions derived from the degassing of mineral waters. They require frequent maintenance to maintain the resource's operating capacity. The presence of these water resources and the engaged protection policies are a real opportunity for a concerned territory. Natural mineral or thermal water as a 'local product' is a recognized cultural, economic and social local enrichment. Through the deployment of environmental policies, natural mineral and thermal water can be a sustainable development factor.

Myths or stories

How were mineral waters valued over time? Not only as spa therapy or following the current fashion by consuming bottled water, sparkling or plain. Since the beginning of the 20th century, there was a succession of three other uses of mineral waters in France.

Between 1896 and 1902, Henri Becquerel discovered radioactivity and Pierre and Marie Curie isolated the radioactive element radium that would become a new magic potion for decades. Between 1920 and 1940, ingestion as a beverage and baths of radioactive water were medical therapeutics. Many mineral waters in France have based their marketing on this salutary radioactivity.

The pellets 'Pastilles Vichy' are an octagonal white candy created in 1825 from a combination of ingredients among which mineral salts, extracted from mineral source water from the famous spa town of Vichy, kept all the digestive properties of the water. Since then, these candies have always been consumed in France.

The use of mineral waters by the cosmetic industry is nowadays the most recent major focus of valuation of their physicochemical characteristics (Avène, La Roche Posay, Uriage, Vic, etc.). Curative powers, softness and protection, hydration, beautiful skin, anti-aging innovation and antioxidants are many effects and positive actions highlighted by the cosmetics industry. In our modern times, urban life with its pollution causes hypersensitized skin. The benefits of thermal waters in cosmetics are the last marketing argument of the mineral water story.

French
Geological Survey

Géosciences pour une Terre durable
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Philippe Négrel is the deputy director of the Laboratories Division in the French Geological Survey (BRGM). He was awarded a PhD in isotope geochemistry in the University of Paris 7, France. He specialized in radiogenic (Sr, Nd, Pb) and stable isotopes (O, H, B, Li) in environmental studies focused on surface and groundwater, in rocks, soils, sediments and air, and acted as senior research project leader in BRGM. He is Vice President of the International Association of GeoChemistry (IAGC) and Deputy Chair of the EGS Geochemistry Expert Group.

Philippe Vigouroux is a hydrogeologist in charge of thermal and mineral water in the Water Division in the French Geological Survey (BRGM), specialized in interdisciplinary approaches for characterizing mineral water resources. He was awarded a PhD in hydrogeology in the University of Montpellier. He is Vice President of the French Association of Hydrothermal Technology.

Germany

Introduction

The use of thermal waters in Germany can look back on a long and eventful history. Bathing culture has been especially popular since ancient times (when southern Germany was a Roman province), flourished during the Carolingian Renaissance and is still popular today.

In Germany, major fields of natural and artificial geothermal springs accumulate along huge geotectonic structures like the alpine deformation front, normal faults lateral to the upper Rhine rift valley, and the northern and southern rim of the rhenohercynian belt (rhenish massif northern thrust and Taunus-Hunsrück southern rim suture zone). Brines occur near Northern and Eastern German salt domes, and mineral and acidulous waters and CO_2-ascension are often associated with subrecent volcanic areas like the Volcanic Eifel, Vogelsberg and Rhön Region. As a result, manifold opportunities for thermal water applications are provided in German geological environments.

This section will give a brief insight into the history of those thermal water applications in Germany with a focus on one of the most important thermal water sights in German history: Aachen.

The present-day most prominent embodiment of thermal waters in Aachen is represented by the 'Elisenbrunnen', illustrated in the background picture.

Why it is special and why it is good for our well-being?

One of the first German discourses on the curative potential of thermal waters was published by Johann Eichmann (also known as Dryander), in 1589. A connection to underground processes was made during the following decades and summarized in 1688 by Franciscus Blondel from Aachen, who was one of the first German spa doctors. He described the interaction of water with 'Mineralia' and 'Metalla' on its way through the underground at different temperatures to be the reason for the diversity of thermal waters and their 'miraculous medicative effects' in his book.

Although the 'trial-and-error' healing methods of the past have been replaced by more process-oriented modern medical sciences, some applications like bathing, rinsing, affusion, drinking, steam bathing and inhalation are still known to exhibit curative effects even today. Not only are there heat applications for body temperature control, muscle and joint relaxation, but also several ionic ingredients have been identified as having specific effects, whereas the influences of other ingredients today are at least questioned. For bathing, the main pharmacologically active ingredients are assumed to be carbon dioxide, sulfide, radon, sodium chloride brine, iodide and fluoride. When imbibed, calcium, magnesium, iron, zinc, copper, bicarbonate, sulphate, fluoride and iodide are assumed to develop positive pharmacodynamic, adaptational or electrolyte substitutive effects on the gastrointestinal, urinary, metabolic and cardiovascular systems. Diverse afflictions of the respiratory system can be eased by inhaling the fumes emitted by thermal springs through moistening and aerosol transport of active aqueous ingredients into the trachea-bronchial system.

Use of the resource in a historic context

In ancient times as a Roman Province, bathing culture was brought to the southern and western parts of present-day German territories and to the Germanic tribes by their historic colonial masters in the first centuries after Christ.

The thermal springs in the Aachen region were first enclosed by the Romans, dating as far back as the birth of Christ, and were destroyed and expanded several times during the long history of Germanic aggression against the Roman military camp on their erewhile home country. After four centuries under Roman reign, the thermal bathing facilities were completely destroyed in the course of the great Migration Period and the final invasion of the Franks into the Cisrhenian Rhineland.

With the decline of the Roman Empire in the fifth century AD and the invasion of the 'barbaric' Germanic tribes, remnants of the Roman culture, like unholy ornaments, mosaics and heathen temples, were often torn down and used as material for raising new buildings. Bathing had been central to the Roman culture, whereas the Germanic tribes saw it more as a necessity during the Middle Ages.

This changed again in the 14th and 15th century, when Renaissance resurrected Roman heritage. Then, the mainly pleasurable activity of bathing developed into balneology and became a part of early health sciences by the 17th century. At the time, one of the most important balneologists (spa doctors) was Franciscus Blondel, from Aachen.

In Aachen, medieval developments had led to an almost complete destruction of the Roman thermal water facilities. For a period of almost four centuries, there is no evidence of further use of the thermal springs known to historians. Not until Pippin the Younger, first of the Carolingian Kings of the Franks, used to spend his winter holidays bathing in the remains of the Roman thermal baths that he had had restored and stripped of their Roman idols. At the center of his Frankonian realm, Pippin's son Charlemagne, protector of the papacy and Holy Emperor of the Romans, chose Aachen for his main residence and the center of his power. During the Carolingian Renaissance, the Aachen Palatinate Chapel, which nowadays is a part of the Aachen Cathedral, was built on top of the ruins of a second old Roman bath, finally plugging one of the thermal springs. Pippin's Thermae, however, survived first under royal and then under municipal control, until sadly almost the whole city was destroyed by a huge city fire in 1656.

Roughly 30 years later, Franciscus Blondel published his description of Aachen's yet again – like a phoenix from the ashes – newly erected bathing district and the medicinal benefit of its thermal waters. However, now they were additionally used for the cleansing of wool in the textile industry.

Germany

The resulting new bloom of bathing culture to the German territories culminated in the 19th and early 20th century. Thermal springs were now assessed from a more scientific perspective. Numerous medicinal, hydro-chemical and geological descriptions of single thermal springs in the German territories of the 19th century were summarized in the eclectic 'German baths book' by Konrad Keilhack in 1907. With the foundation of the German Baths Association in 1892, an institutionalized basis was established for regional political regulation that found its way into the German 'spa town law' regulating town name affixes and special visitors' taxes.

As Aachen's bathing district of the late 17th century was again completely destroyed in the course of WWII, today there is only a little evidence left of the impressive historical relevance and once so magnificent appearance of the Aachen thermal springs. Only the modern 'Carolus-thermae' are still supplied by water from the 'Rosenquelle' spring and the sulfurous water of the 'Kaiserquelle' spring can still be accessed at the 'Elisenbrunnen', not just as a drinking dare for freshman students.

Nowadays in Germany, thermal, mineral and healing waters and springs are used for bottled water, production of CO_2, salt and heat, as well as for balneological application.

Threats and protection

Even though the protection of groundwater springs has been legally regulated in all the German territories since 1926, the protection of thermal springs has not always been as well managed. As a product of the deep underground, requirements for protection of thermal and mineral waters are substantially different from those of shallow drinking water wells. As migration pathways are buried in deep geologic formations, threats to the quality or functionality of the hydrothermal system can even occur in several kilometers distance from the springs. Therefore, the designation of protection zones is extremely complicated as the hydrothermal system of each single spring has to be identified and characterized individually. This often results in conflicting interests for groundwater. Agricultural and mining industries are affected by scientific discussions of complex possible flow paths, as the whole flow pathway from the recharge area to the spring needs protection from interferences with respect to quality and quantity of thermal water. In recent years, isotopic tritium analysis has become an important tool to identify the flow system and groundwater age for definition of protection zones.

Acknowledgements

In Germany, a great many experts have given us the opportunity to partake in their knowledge of the geologic history, regional distribution, natural scientific description and predominant applications of thermal and mineral waters by composing it into comprehensive books. Among those, some of the first to mention are Gert Michel, Werner and Hanna Käss, Konrad Keilhack, Walter Carlé and Karl Fricke, whose excellent lifetime achievements the possibility to write the above texts rests upon. Information on Aachen and its thermal waters were mainly gleaned from historic to recent publications of Franciscus Blondel, Wilhelm Friedrich Leopold Zitterland, Ignaz Beissel, Hans Breddin, Horst-Robert Langguth and his students.

Federal Institute
for Geosciences
and Natural Resources

BGR

Thomas Himmelsbach is head of the Division for Groundwater Resources of the German Federal Institute for Geosciences and Natural Resources BGR, Hannover. He is a hydro-geologist by profession and gained his PhD at Karlsruhe Institute for Technology. Aside his activities at BGR, he teaches as associate professor at the Hydrogeology Department at KIT.

Christoph Weidner is a research associate at the Division for Groundwater Resources of the German Federal Institute for Geosciences and Natural Resources. He graduated in hydrogeology at the RWTH Aachen University and today focuses on the hydrogeology of fractured bedrock.

Greece

Introduction

The history of Natural Thermal Resources begins in the intervening period of 4000 and 3000 BC. It appears that Indians were the first who used thermal waters, and Persians, Egyptians, Jews followed. The therapeutic properties of water were probably introduced to ancient Greeks by Egyptians or Persians, although they might had discovered them by themselves. They knew, however, that water is a structural element and a precondition of life for every organism on Earth. This is why they ascribed many supernatural, magical and curative powers to water. Water ranked first among the deified elements of nature. The father of all was the Ocean, and gods and heroes used to bathe in springs with miraculous properties to retain or regain their strength.

In the following years, Romans, who were the prime admirers of thermal baths, even had punishments for those who did not bathe themselves. Byzantines, in compliance with their Christian ethics, opposed thermal baths. Nevertheless, they built beautiful baths, later maintained by Ottomans.

In modern Greece, the first governor, Kapodistrias, worked on the reconstitution of the thermal baths. In 1950 the Hellenic National Tourism Organization (EOT) was founded. From 1960 to 1970, a large blossom of spa tourism emerged in the following regions: Methane, Edipsos, Ypati, Kamena Vourla, Loutraki etc. For the next 30 years, there was no organized effort to promote spa tourism in Greece. It was only after 2005 that, thanks to the amendments on the legislative framework, development of thermal tourism arose again.

Why it is special and why it is good for our well-being?

The hydrotherapy spa is a particular branch of alternative medicine, which promotes the prevention and treatment of diseases, but also the wellbeing of both body and soul. In spa hydrotherapy, the organism is treated as a whole, in accordance with the principles of holistic consideration. So, the therapy does not focus on one symptom but on all symptoms exhibited by an organism.

With the advancement of science and chemical analysis of thermal waters, researchers concluded that the therapeutic properties of baths can be attributed to the presence of metal salts, specific colloidal substances and rare gases. Other studies attributed the healing powers of the thermal waters to radiation, due to their small content of radioactive elements. A more modern perception is that spa incorporates the concept of an irritant treatment in certain organs, such as iodine in the thyroid gland and sulfur in joint cartilage. The incentives that the body receives during thermal treatment are divided into mechanical, such as hydrostatic pressure and buoyancy of the water; thermal, when the water temperature differs from the temperature of the body; chemical, where important elements are absorbed through the skin; and finally environmental incentives, especially relief from stress and inner tranquility.

Use of the resource

The use of Natural Thermal Resources is mainly in therapeutic applications, internal or external. The category of internal hydro-therapy includes drinking therapy, inhalation and nasal, oral and gynaecological washes. External applications include thermal spa (cascades, hydromassaging, hydrokineso-therapy, steam) mud therapy, thalassotherapy (aerotherapy, sunbathing, sandbath, balneotherapy with seawater, Jacuzzi with seawater bubbles, underwater sprinkling, rain shower etc.).

Drinking therapy is proposed to treat symptoms of digestive disorders and for the liver, kidneys and spleen. In Greece, there are many hot springs suitable for drinking therapy. The most famous are: Traianoupolis - Alexandroupolis Evros, Loutraki – Perachora Korinthos, Platistomo Fthiotida, Kokkino Nero Karitsa Larissa, Therma Mirynas Lemnos, Kivotos Grevena, Ammoudara Kastoria, Agiasos Lesvos Gianna Kilkis, Agrapidies Limnohoriou Aetos Florina, Thermies Paranesti Drama Souroti Vasilika and Xino Nero Florina.

Inhalation therapy is indicated for the treatment of diseases of the respiratory system, such as bronchial asthma and chronic bronchitis. The most appropriate sources for inhalation are the sulphur ones, which emit vapours. In Greece, suitable springs for inhalation are: Traianopoulis Evros Amarantos Ioannina, Loutrochori Skydras, Kavasila-Pixaria Konitsa Smokovo Karditsa, Caiaphas Zacharo, Edipsos, Polychnito Lesvos, Efthalia Lesvos, Adamas Milos, Kythnos Agrapidies Florina, Kivotos Grevena, Amarantou Ioannina.

Thermal bath therapy is recommended for various diseases such as chronic rheumatic diseases (e.g. rheumatoid arthritis, degenerative joint diseases), skin diseases, gynaecological diseases, diseases of the nervous system, migraines etc. The oldest and most popular spa baths of Greece are Nisyros, Kyllene, Caiaphas, Loutraki, Ypati, Kamena Vourla, Thermopylae, Platistomo, Smokovo, Thermi of Lesbos, Lagadas, Ikaria, Methana, Edipsos.

Mud therapy is based on the use of mature mud. The therapeutic effect is dual, topically to the skin by spreading or by total immersion of the body, and globally by the substances that penetrate the body. Mud therapy is recommended for skin diseases, arthritis, gynaecological diseases, gouty arthritis, eczema, psoriasis. Popular mud baths in Greece exist in Kavala, in the mud bath facilities of Krinidae, in Pikrolimni Kilkis etc.

Thalassotherapy uses seawater, seaweed and mud. It may prove beneficial in diseases of the cardiovascular system (e.g., hypertension), respiratory problems (e.g. asthma and chronic bronchitis) and dermatological disorders (e.g. psoriasis, and eczema). It is also highly effective in musculoskeletal disorders, such as pains and spasms of any etiology, cervical syndrome, lumbago, arthritis, etc., and helps to improve the immune system and sleep quality.

Greece

Threats and protection

According to the legislation of Greece, it is ensured by Presidential Decree that every natural thermal resource, within a defined protection zone, is under protective measures. A natural thermal resources protection zone is an area where both construction of facilities and any activity or function that may be hazardous to the resources are prohibited, in order to protect the quantity and quality of thermal waters.

Myths or stories

The therapeutic properties of the thermal springs were already known in Greece in ancient times and were connected with many mythical deities, regarding the beneficial and therapeutic substances, suitable for the treatment of bath patients. Defkelionas and Pyra, after the devastating flood that caused Zeus to punish people for the sins of Prometheus, found refuge in Edipsos of Evia. There, following the advice of Hera, to gain many and strong children, they had a bath in the warm spring waters and thus acquired Hellin, father of all the Hellenic tribes.

The nymphs, daughters of Zeus who were also considered deities of medicine and divination, were called Naiads (or Hydriades) and were associated with the healing and prophetic properties of the waters. According to tradition, the famous Castalian Spring, took its name after the nymph Castalia, who lived near Delphi. Goddess Artemis, sister of Apollo, who was also called Lusia or Thermia Artemis, used to bathe in various caves in Greece.

According to another legend, the waters of the source Caiaphas were attributed with healing properties, as it was the place where the Centaurs washed their wounds after the battle with Hercules. Very important sources with special healing properties, according to mythology, are the hot springs of Thermopylae, created by Hephaestus from underground fire (of which the volcanoes were created), at the request of the goddess Athena. There, Hercules, who was under the protection of Athena, used to bathe to regain his lost power after each feat, but also for the relief of pain.

Hippocrates used thermal springs on Kos and Nisyros to cure his patients. In ancient Athens, it was a tradition for the newlyweds to bathe in Krini Kalliroi, at the bank of the Ilissos River, because they believed the waters to have a beneficial impact on fertility.

According to a local legend, several men who entered the cave Provata in Milos were kidnapped by elves. The cave was located at the base of a rock near the chapel of St. John, and functioned as a kind of sauna with therapeutic properties. The person of interest was sitting in a chair in the centre of the cave, while hot steam at the temperature of 38-40 °C was coming out of volcanic holes. An earthquake demolished the cave in 1992.

According to another tradition, Olympias conceived Alexander after having bath at the Therma Spring of Samothrace. The thermal spring attracts childless women, due to its reputation.

Institute of Geology
and Mineral Exploration

Athanasoulis Constantinos has a Bachelor Degree in Geology, University of Uppsala, Sweden, an Msc in Mineralogy – Petrology, 3 years of experience in the Geological Survey of Sweden (SGU), and 29 years of experience in the Institute of Geology and Mineral exploration of Greece (IGME). From 2001 to date, he has been a member of the Department of Water Resources and Geothermal Energy. He participates in administrative and management activities of IGME. He has also participated as supervisor in the organization and evaluation of many European and public investment projects and in seminars, publications, reports, announcements and committees for IGME. He is a member of the national commission of therapeutic natural resources.

Xenakis Markos has a Bachelor Degree in Geology, National University of Athens (1984). His experience includes research at the Institute of Geology and Mineral Exploration of Greece (IGME) from 1986 until now. He manages and supervises many geothermal research projects. A member of the Department of Water Resources and Geothermal Energy, he participates in seminars, publications, reports, announcements and committees for IGME and is a member of the National Commission of Therapeutic Natural Resources.

Hungary

Introduction

Hungary is a major country for mineral and thermal waters. The Pannonian Basin lies on a positive geothermal anomaly, with an average geothermal gradient of about 5 °C/100 m (Dövényi et al., 1983) and a mean basal heat flow value of 100 mW/m2 (Lenkey et al., 2002), which is about one and a half times higher than the average continental crust value (Dövényi and Horváth, 1988). Due to this fact, the average thermal water outflow temperatures are 35-40 °C, reaching 60-65 °C at 1000 m depth. Hungary ranks as the 5th country in the world in terms of thermal water resources after Japan, Iceland, Italy and France. Mineral waters are usually either high-temperature with low mineralization or lower temperature with high mineralization, but Hungarian thermal waters are rich in dissolved minerals, having at the same time higher temperatures.

Two main thermal water aquifer types can be differentiated, the few thousand meters thick (Miocene) porous, intergranular, multi-layered sediment sequences and the (Palaeozoic, Mesozoic) carbonates (often karstified) of the basement, including occasional fracture zones of the altered fissured basement rocks.

More than 60% of operating thermal wells have a Na-bicarbonate chemical composition. The porous intergranular sediments mainly contain Na-bicarbonate type waters, while the carbonates of the basement are either Ca-Mg-bicarbonate in the case of regional flow path with recharge, or NaCl type thermal waters in the case of closed reservoirs.

Why it is special and why it is good for our health

The widespread use of thermal springs in Hungary started with the Romans more than 2,000 years ago. Abundant Roman ruins, including spa remnants, clearly show the distribution and evolution of Roman settlements in the Pannonian Basin. Aquincum (located in what is now northern Budapest) occupied a strategic position, becoming a permanent military base under the Emperor Traianus in 106 AD, and was part of the Roman border protection system (limes). Eighteen spas operated at Aquincum, which shows that the military base (castrum) was also an exceptional spa city in that period. The springs in Aquincum were captured in different ways, but all of them had a carved stone that informed the people about the healing properties of each spring.

During the westwards migration of barbarian tribes, almost all of the Roman spas were destroyed. The first reference to a spa after the settlement of what later became the Hungarians can be found in a letter of King Stefan's (1015) in a deed of foundation for the Benedictine Abbey in Pécsvárad, that they also have to build a spa with a proper number of spa-servants. It was only in the 1100s that the former spas of Buda started to enjoy a revival. Christianity played an important role in their reopening, with monastery orders such as the Johanniter Order, the Franciscan Order and, later, the Order of Mercy building new hospitals and churches. The (re)construction of spas started relatively late, in the 14–15th centuries under the Anjou house and king Zsigmond.

Spa culture was greatly developed during the Ottoman occupation in the 16-17th centuries. Numerous Turkish spas were built during this time, of which a few are still in operation (Császár, Király, Rác and Rudas in Budapest and a spa in the city of Eger). The first official distinction between mineral and healing water was introduced in the 16th century, during the Ottoman occupation.

The first legislation on mineral waters was introduced by the Austrian-Hungarian Empress Maria Teresa in 1762, who ordered a survey of the Empire's mineral waters regarding their composition, usability and exportation possibilities.

The establishment of a county-level chief-doctor system, the support of the emperors and kings who followed Maria Teresa, and the continued surveying and marketing the mineral waters also helped the development of balneology. Interestingly, several unproductive oil wells were converted to geothermal wells. This was the start of new research to understand the relationships between geology and hydrogeology. Associations and organizations dealing with mineral waters started to operate one after the other at the beginning of the 19th century.

Use of the resource

According to the more than 100 years old Neuheim Decree (1911), mineral waters in Central Europe were considered to be those which had more than 1000 mg/l total dissolved solids, or contained biologically active parameters like sulphur, iodide, bromide, fluoride or silica. This classification was modified in order to harmonize Hungarian regulations with those of the European Union.

Mineral waters are used in many different ways. They can be used as:

- Bottled mineral waters or drinking cures in medical thermal spas, or in spa drinking halls
- Thermal and medical thermal spas
- Mineral waters applied in balneotherapy

Mineral water can be consumed without limitation, but medical waters may be consumed only under medical supervision. The first comprehensive analyses of thermal waters were carried out in 1721 by Lőrinc Stocker, a physicist from Buda, who published his results in the 'Thermographia Budensis'.

The combined use of medical water, mud-pack and weight bath, the latter developed by doctor Károly Moll from Hévíz, and mineral water drinking cures, together form part of the complex and renowned Hungarian balneo-therapy. This Hungarian balneotherapy is available through the Hungarian national health care system, providing high-quality service for all those who have health insurance, and covering a very wide range of medical problems (e.g. locomotive, gastric and enteric, respiratory organs, cutaneous, nervous system, gynaecological diseases, and their prevention).

The spa waters are categorized mainly by their macro-element compositions. Ten major mineral water types can be differentiated with the following major or characteristic parameters: Na-bicarbonate, Ca-Mg-bicarbonate, chloride, sulphate, sulphur, iodide, bromide, radon, iron and CO_2. Some thermal waters can have high organic matter content.

The mineral and thermal waters were exploited through captured springs until the beginning of the 19th century. The first drilled

Hungary

artesian well was 14 meters deep and was drilled in the town of Ugod in 1825. In order to get a stable source and to guarantee as far as possible a constant water composition, a near 38 m deep well was drilled in Harkány by Vilmos Zsigmondy, the famous Hungarian mining engineer, in 1866. He was the one who later (between 1868-1878) invested all his money in drilling a 970 meter deep well in Budapest. This Városliget I. well had a 72,000 litre/day yield at 74°C, and operated until 2000.

Budapest is the only capital city in the world with more than 100 thermal springs and wells. Its richness in healing waters is also unique. Five of its operating thermal spas are monuments. The only cave-spa in Europe can be found at Miskolctapolca, 200km NE of Budapest.

Threats and protection

Protection of operating mineral and thermal water production sites is ensured by national laws. Under the Hungarian law enforcement system, the main aspect in the judgement of the vulnerability and protection of groundwater is based on the time during which a potentially polluted infiltration from the surface can reach the aquifer (within 50 years).

Regional, large and general protection is ensured through a Government Decree on the protection of groundwater. This regulation includes restrictions in order to protect groundwater, forbidding the introduction of hazardous material or their breakdown products into the groundwater both directly and indirectly. It also defines sensitivity categories based on the conductivity properties of the near-surface geology and the depth of aquifers, also taking into account the local geology.

Another Government Decree is about safeguarding drinking water protection areas, which also include mineral and medical water (both the sources and the facilities). Vulnerable (captured springs, karstic or shallow aquifer) production sites also have delineated water protection areas where certain activities are prohibited, limited, or require special authorization.

A ministerial decree regulates how ground-water resources can be abstracted and what the professional requirements of well drillings are, including the requirements of physical and chemical monitoring of the abstracted water and the geophysical logging of the wells.

The most relevant threat is the production of thermal water without re-injection, which in the long term will cause significant drawdowns, especially where more wells operate close to each other and where other sectors (e.g. agriculture) also use the same aquifers. The few operating re-injection wells usually re-inject the used thermal water into upper aquifers rather than into aquifers from which the water was previously abstracted, injecting higher concentrations of dissolved minerals, sometimes even rich in organic compounds, into aquifers with lower mineralization.

Myths or stories

Some Byzantine documents mention the use of thermal waters by the Huns and Hungarians. The famous Byzantine historian, Priscus of Panium, who twice visited the court of Attila the Hun in the middle of the 5th century, mentions that one of the Hun chiefs had a thermal bath built of stones. Another letter states that emperor Constantine VII Porphyrogenitus ordered a Hungarian bath made of leather in the 10th century. One of the many myths of Lake Hévíz tells us that the Virgin Mary created the spring after the intercession of a Christian nurse. The nurse wanted to cure an invalid child. The hot spring water and the steamy mud cured the child, who is believed to have been Flavius Theodosius, the emperor of the East Roman Empire.

For many years, the pool of the hippopotami at the Budapest Zoo was filled with water from the nearby thermal well of the Széchenyi Spa. Based on a local legend, the medical thermal water of the Széchenyi Spa had a beneficial and aphrodisiacal effect, and it is a fact that many hippopotami currently located in European Zoos have Hungarian progenitors.

Geological and Geophysical Institute of Hungary

Teodora Szocs, PhD in hydrogeology, head of the Department of Hydrogeology in the Geological and Geophysical Institute of Hungary (MFGI). Hydrogeochemical expert in a number of international projects, including transboundary joint aquifer management and geothermal energy resource evaluation. Hungarian representative in the Water Resources Expert Group, EuroGeoSurveys. Member of the Hydrogeological Subcommittee, Hungarian Academy of Sciences. Currently Vice President for Europe of the International Association of Hydrogeologists (IAH).

Ireland

Introduction

Because of its copious and reliable rainfall, Ireland has an abundance of springs. Many of the larger ones issue from the Carboniferous limestones that occur in over 50% of the country.

In the 18th Century, warm and cold springs were developed as spas in various parts of Ireland. The popularity of these springs was short, and most were in decline by 1850. Today only Lisdoonvarna Spa, County Clare is still operating.

Springs in Ireland were places of religious significance for the pre-Christian Druidic religion. In the Christian period they became holy wells, under the patronage of various saints. Cures for many different ailments were attributed to water from these wells.

Ireland's natural mineral waters and spring waters derive mainly from limestones and generally have a calcium-bicarbonate hydrochemical signature, low nitrates, and are hard, with about 400 mg/l total dissolved solids. This is due to the bedrock aquifer composition, protective layer of subsoils, high rainfall and recharge rate, and generally deep (>500 m) production boreholes used by natural mineral water producers.

Why it is special and why it is good for our health

Water quality and natural groundwater chemistry are determined by the nature of the rocks and subsoils that the water interacts with; on the degree of natural protection that the groundwater has; and on land use and meteorology.

Spring waters are mainly calcium-bicarbonate type, with temperatures typically 9–11°C. Groundwaters from limestone are hard to very hard, with Electrical Conductivities (ECs) of 550–650 uS/cm, but from non-carbonate aquifers are much softer, with ECs of 150–250 uS/cm. Elevated iron and manganese can occur. Most warm springs are calcium-bicarbonate, with a few having a more sodium-chloride signature. Sulphur-rich 'chalybeate' springs are also known in shale-rich rocks and, together with warm springs, were used as Spa Wells. Some Holy Wells are said have specific curative properties. Some wells associated with mental health improvement turn out to have elevated lithium concentrations.

Ireland's solid geology is dominated by Precambrian to Lower Carboniferous-age siliceous rocks. Lower Carboniferous limestones are significant, and occur mainly in the centre, with the older non-carbonate rocks forming a resistant mountainous 'rim'. Lower Palaeozoic rocks include silicilastics, igneous and metamorphics. Within the Republic, there are very small inliers of Permo-Triassic sandstone; Mesozoic sandstones, chalks and basalts occur in Northern Ireland. Glacial deposits of till and gravel, along with post-glacial peats, cover much of the bedrock across Ireland.

In all rocks, primary porosity is very rare. Groundwater flow and storage depends upon fractures. Chemical dissolution of pure limestones creates significant groundwater flow conduits. Well yields, spring flows and groundwater fluxes are significantly higher in karstified pure limestones than in fractured impure limestones. Features unique to the karst environment include turloughs (seasonal lakes that fill with groundwater from below), limestone pavement, sinkholes and dolines.

Unconsolidated Quaternary deposits generally act as a protective, filtering layer over the bedrock aquifers, but localised gravel deposits can contain groundwater resources.

The island of Ireland faces the northwest Atlantic Ocean, the dominant influence on our climate, which is generally mild and wet. Average annual rainfall of c. 800–2,800 mm is highest in the western half of the country, especially over higher ground. Potential groundwater recharge is generally ample, being lowest in the southeast and east, and highest in the western half of the country, but not all of the potential recharge can be accepted or retained by certain aquifer types.

Forty-two warm springs and warm shallow groundwater occurrences have been recorded to date in Ireland. All warm springs issue from faulted and dolomitised Waulsortian Limestones and are associated with the Iapetus Suture, a major northeast–southwest trending structure. They are located in two clusters: Leinster, in the east of the country, near Dublin; and Munster in the southwest, north of Cork City. The springs range in temperature from 12–24.7°C and are elevated with respect to average Irish groundwater temperatures (9–11°C).

Use of the resource

Groundwater provides about one third of drinking water in the Republic of Ireland. Public Water Supplies utilise 20-25% groundwater overall, with the balance coming from surface water, but some regions in the midlands use 70-100% groundwater. Most Private Group Water Schemes draw on groundwater from springs, shallow wells or boreholes. Nearly all dwellings and farms with individual water supplies have boreholes; Ireland has a large rural population, with Census estimates of ca. 170,000 wells.

Bottled water's popularity in Ireland has increased exponentially since the 1980's, although its per capita consumption is a quarter of the Western European average. There are four recognised natural mineral water producers in Ireland: Ballygowan, Kerry Spring, Glenpatrick, and Tipperary. Other bottled groundwaters, mainly from boreholes, are sold as Spring or Bottled Waters (sensu EU Regulations). The majority of the natural Mineral and Spring waters are derived from pure limestone bedrock aquifers, with the exception of a handful that take groundwater from Devonian or Carboniferous sandstones.

Some of the warm or chalybeate springs have been utilised in the past as therapeutic spa wells, although only Lisdoonvarna is used. Waters associated with skin remedies are often high in sulphur. Wells connected with

Ireland

"strengthening weak children" are generally iron-rich. The well in County Kerry's Gleann na Gealt ("Valley of the Lunatics") contains elevated lithium and was used in treating mental illness.

In Mallow, Co. Cork, warm water (19°C) is used to partially heat a municipal swimming pool. This is the only known current example of direct use of the Irish warm springs. The spa waters at Mallow were compared favourably to the English springs at Bristol and Buxton.

Myths or stories

Many place names in Ireland take their names from groundwater features, particularly in karst limestone areas. The Burren, the famous karst limestone plateau in western Ireland, is derived from the Gaelic for "stony place". Tobar or Tiobrad means "well" in Irish, and becomes part of many place names with springs. Uisce (water) is anglicised to Iska, Isky, and Isk, such as in Rooskey ("marshy place"). Uaran or Fuaran (fresh or cold water springing from the earth), has changed to Oran, such as at Oranmore in County Galway, an area plentiful in large springs.

Ireland is said to have as many as 3,000 holy wells. Many sites consist of three elements: the well or spring; a sacred tree, usually very large and very old; and a hill or standing stone. In Irish myth, wells and springs are depicted as originating in the Otherworld, from where water flows into our world to fill springs or form rivers. It was believed that drinking from these holy waters or bathing in them would bestow the power of the Otherworld in the form of poetic inspiration, wisdom, or healing.

Early Christians blessed such wells and adapted existing practices associated with them. Many of the warm springs would have been known in pre-Christian times, and it must have been a matter of great wonderment to our pre-Christian ancestors to find a well that never froze in winter. Many holy wells were dedicated to the national apostle of Ireland, St. Patrick. There are many Lady's Wells and Bridgid's Wells across the country, as well as those dedicated to other saints.

Geological Survey of Ireland

Taly Hunter Williams - EGS National Delegate and Senior Hydrogeologist working in Groundwater Programme.

Italy

Introduction

Due to its archeological and geological heritage, Italian territory has inspired the so called “trip to Italy” during the last centuries. Evidence of recent/current morphological, seismic and volcanic processes may be observed, like eruptions of Etna, the highest European active volcano. The Italian main morphological regions are the Alps, the Apennines, the wide Po-Veneto-Friuli Plain and the minor and fragmented coastal plains. In addition, sea coastline processes are also evident.

Concerning groundwater resources, they are hosted in both large and small alluvial and coastal plains. In addition, the calcareous rocks occurring in Alps, Apennine and Sicily yield large amounts of groundwater from springs and as well volcanic rocks usually host quite large amounts of groundwater. Instead, the magmatic and metamorphic rocks of Alps, Calabria and Sardinia and the large areas with mainly impermeable sediments of Apennine and Central Sicily display only minor amounts of groundwater.

Furthermore, the presence of active volcanoes witnesses uplift processes of hot vapor and gas from deep levels along fractures and faults. These vapor and gas interact with both host rocks and groundwater and lead to cropping out of thermal-mineral springs, frequently available for thermal bath purposes.

Why it is special and why it is good for our well-being?

A great variety of geological, morphological and climatic environments characterizes the Italian territory transmitting to our groundwater unique and special properties. Considering groundwater resources everybody usually thinks to water supply, but groundwater, when it has characteristics of mineral and thermo-mineral water, may be used both for drinking and therapeutic purposes.

Considering drinking use, Italy is the country in Europe where more bottled water is consumed (192 l/inhabitant/year), reflecting the large number and variety of available resource and awareness of the benefits. Mineral waters are essential first of all for the absorption of calcium mainly in case of osteoarticular problems; moreover mineral water treatments have greater chance of success to purify liver, kidneys, intestines and stomach. Benefits from these therapies are so important to be inserted in convention with Italian national health system.

Referring to therapeutic uses (crenotherapy), already known in ancient roman times, we have witnessed in recent years to a rediscovery of SPAs (from Latin Salus Per Aquam), due to the increasing need of relax from stress of modern life. In Italy a widespread and extensive presence of these structures allows the use of waters (drinking - hydropinotherapy; breathing; bathing; mud-bathing) at different temperatures even outdoors and in the mountains, with snow, sun, almost anywhere. Water uses vary from simple relaxation to proper medical treatment to relieve and soothe ligaments and bones. The presence of substances such as sulfur, iodine, chlorine, bromide, arsenic, lithium, calcium, gas and radioactive elements gives water therapeutic virtues acting as an anti-inflammatory on articular cartilage and making recommended for respiratory problems. Some centers use thermal waters, or rather their vapors, to fight sinusitis, ear infections and other diseases. In addition to the beneficial effects of treatment for health, thermal waters are also used for beauty.

Water resources distribution

Italy is one of the richest countries in the world in thermo-mineral springs and its ancient thermal bath tradition is well-known all over the world, also for the attractive natural scenarios where springs are located. Listed below, a summary of some Italian thermal bath localities:

- Sirmione (Lombardy). Internationally known for its sulfide-sodium-chloride-bromide-iodine waters at 69°C; recommended for otolaryngoiatric, cardiovascular, respiratory, rheumatic and dermatologic problems.

- Abano (Veneto). Known from the prehistoric age. Sodium-chloride-bromide-iodine and radioactive waters with about 80°C are suggested for rheumatic, gynecologic and respiratory pathologies.

- Saturnia (Tuscany). Sulfide water from a natural crater with a yield of 800 l/s and 37°C are advisable for cardiovascular, respiratory, muscular, skeletal and dermatologic therapies.

- Ischia (Campania). Sodium-chloride-sulphate-alkaline waters known from ancient time having 19 to 74°C are indicated for rheumatic, dermatologic, muscular, neuralgic, gynecologic, respiratory and cardiovascular problems.

Other worth noting SPA localities are: San Pellegrino, Boario and Bormio (Lombardy), Grado (Friuli-Venezia Giulia), Salsomaggiore (Emilia-Romagna), Chianciano and Montecatini (Tuscany), Fiuggi and Viterbo (Latium).

Threats and protection

The depletion of groundwater is a phenomenon that threatens the water resources not only in terms of quantity and availability, but also because it can sometimes irreversibly alter the quality of the resource. The main causes of this depletion are attributable to:

1. Slower charging (quantity): due to a strong water withdrawal or to a change in the terms of infiltration (e.g. a result of deforestation or increase in impervious surfaces);

2. Pollution of groundwater (quality): pollution caused by agricultural, industrial and civil uses.

Moreover, over-exploitation of groundwater can have several consequences:

1. Decrease of groundwater level;

Italy

2. Phenomena of subsidence, effects particularly dangerous in urban areas;

3. Saline intrusion in coastal areas, often causing irreversible effects on the use of water resources.

At national level, the Governmental Decree 152/06 defines the framework for protecting, preventing and reducing pollution, restoring and improving the state of water intended for particular purposes, ensuring the sustainable use of resources and maintaining the natural ability to self-purification of water bodies.

The achievement by 2016 of a «Good Environmental Status» for all the different types of water (river, lake, coastal marine, transitional water, artificial water bodies and groundwater), is the overall aim of the decree, to be achieved in all significant watersheds through conservation programs, rehabilitation and monitoring integrated as the overall plan of the basin. These objectives are therefore aimed at the sustainable management of the complex water resources.

The Italian legislation identifies ISPRA as referent for the collection and processing of information about the status of water quality.

Myths or stories

Therapeutic properties of Italian thermal waters are connected to several myths and legends.

The «Terme di Viterbo» (or «Terme dei papi»), for example, flow from a fracture 12 km long: thermal water with temperature varing from 40° to 50°C, rich in sulfur salts and calcium bicarbonate, particularly effective for treatment of chronic respiratory, osteoarticular and metabolic diseases and of skin imperfection. The Etruscans were the first to exploit the properties of this thermal water and, when the Romans destroyed the villages built on the Cimino Mt (third century BC), they decided to keep in function the thermal water structures. The Romans took advantage of the resources of the thermal area expanding them; remains are now visible for 11 km along the ancient Via Cassia, where three main sources can be found: Aquae Passeris, Paliano and Bullicame. The popularity of SPAs was also testified by the doctor of the Emperor Tiberius Scribonius Largo. The name «Terme dei papi», as the SPA complex of Viterbo is known today, is related to ancient use by many Popes. The first was Gregory IX, followed by Boniface IX, who suffered from bone pain and came to Viterbo in 1404. After, Nicholas V built a palace on the spot in 1450 (Bath of the Pope) to stay there more comfortably and, a few years later, Pius II made major renovation.

There are also several myths associated to thermal waters in Italy, for example the one about the satyr Taleboo, expert in use of therapeutic herbs. He felt in love with the nymph Procida, who was forced to escape to Ischia, where Taleboo caught up with her. To save her from his offence, Diana petrified her and then Apollo separate her from Ischia, where Teleboo, in turn petrified, begun to cry hard giving place to a healthy spring, like the therapeutic herbs well known by him.

Furthermore, another legend says that one day Saturn, god of the wealthy, got angry with men for their going on and on about wars. Therefore, he threw a thunderbolt on the earth in Tuscany producing a gush of warm sulfide water (Saturnia) which covered the world pacifying it.

Geological Survey of Italy

ISPRA

Daniele Spizzichino has been graduated at the University of Rome La Sapienza in 1999. He got the PhD on Earth system sciences: environment, resources and cultural heritage in 2012. Since 2000 his work has been focuses on: natural risk assessment; cultural heritage protection and management; executive design of mitigation works. He is currently employed – as researcher - at ISPRA.

Lucio Martarelli is a senior geologist at the Geological Survey of Italy – ISPRA. He is mainly involved in hydrogeological and cartographical projects. He was in the Italian National Research Council (CNR) from 1998 to 2001 and professional geologist from 1990 to 1998. He is co-author of scientific papers about Mineral Deposits and Hydrogeology on national and international journals.

Barbara Dessì is a hydraulic engineer, researcher technologist at ISPRA. Her research focuses on natural hazard risk assessment. She is technical support to the IPPC Commission, has taken part to transposition and implementation of Directive 2007/60/CEC and is member of the Water Resource Expert Group for EGS.

Latvia

Introduction

Latvia is located in the central part of the Baltic Artesian Basin which also extends in Estonia, Lithuania, parts of Poland and Russia, including Kaliningrad, Belarus and the Baltic Sea area up to the coasts of Sweden and Finland. The hydrogeological system consists of the Precambrian basement with a depth to basement 300-1800 m, increasing southwards, and sedimentary cover, mainly the Paleozoic. Latvia is well-secured with groundwater stocks: groundwater is the main drinking water supply with potential exploitation resources estimated about 4 691 000 m^3 per day. Low mineralization Ca-HCO_3 freshwater is exploited predominantly and mostly conforms to drinking water standards.

Several types of high-quality mineral waters are distributed in Latvia, like table mineral waters and treatment or medical waters. Mineral waters were studied widely in 1980-ties when the largest deposits of minerals waters were estimated. In considerably large depth also industrial mineral and thermal waters are distributed.

The use of curative and medical mineral Ca-SO_4 waters goes back in history. The first data on medicinal hydrogen sulphide springs related with bogs in the central Latvia – Ķemeri and Baldone – come from the 15th century. The health resort (spa) Baldone was founded in 1797, and was been one of the largest and most popular balneological and mud spas in the Baltic States. Research on the medicinal springs at Ķemeri started in 1801, and the spa was established in 1838. Nowadays the health resort Jaunķemeri (1967) functionates successfully.

The distribution of water resources

According to groundwater exchange and mineralization vertical hydro-chemical zonation is characteristic. The ground waters in Latvia are divided into three main hydrodynamic and hydro-chemical zones:

- Active water exchange takes place in the Quaternary cover and the in the upper part of pre-Quaternary deposits up to the first low-permeability unit downwards. Since the waters are mainly Ca-HCO_3 waters with low mineralization, up to 1 g/l but mainly 0.3-0.4 g/l, the active water exchange zone is also called a freshwater zone, it is 200-600 m thick and is used as the main drinking water supply. The horizons contain infiltration waters and the quality depends on atmospheric and surface waters as well as comprising deposits. However, in some places where gypsum beds over-lied by peat are present, with hydrogen sulphide saturated Ca-SO_4 brackish waters with an average mineralization 2.5-3.0 g/l also are distributed in the active exchange zone.

- All over Latvia, a reduced water exchange zone (slow circulating waters) is distributed below the active water exchange zone. These ground waters are characteristic of a typically high piezometric pressure. In the largest part of Latvia, this zone contains Na-Cl brackish waters with the mineralization of 1-10 g/l. The mineralization of waters in the reduced water exchange zone increases from north to southwest, and with an increasing depth of groundwater horizons the mineralization can also increase by more than 30-40 g/l corresponding to saline waters.

- The stagnant Na-Cl brines with increased content of Br in Latvia are distributed at the base of the artesian basin (Vendian-Cambrian). The surface of the stagnant zone lies 400-1600 m deep and by increasing the depth of horizons mineralization increases. These brines are classified as industrial water, perspective for the extraction of bromine and as a source of geothermal energy. The total mineralization of the brines changes from 35 to 140 g/l, on average up to 115-125 g/l. The highest bromine content >400 g/l was found in the stagnant waters near Liepāja, the south-western Latvia. In separate areas the brines are also classified as thermal waters. Thermal anomalies with 40-60°C warm waters are distributed in the stagnant zone near Liepāja and Eleja in the south of Latvia in more than 1100 m depth.

Why are these waters special and good for our well-being

Waters of active water exchange zone are extensively exploited from wells and produced as bottled drinking waters or extracted as spring waters. Natural mineral waters of low and average mineralization from a reduced water exchange water zone are widely used as table and treatment mineral waters. Mineral waters are with high quality and large resources however, exploitation of them both for balneological needs and filling into bottles still is in incipience.

- Within the active water exchange zone where freshwater circulates through gypsum over-lied by a peat beds Ca-SO_4 waters saturated with hydrogen sulphide originate. These waters for more than a hundred years have been used for curative purposes at the two the oldest vulnerary spas in Latvia – Ķemeri and Baldone. Now these balneologically valuable hydrogen sulphide waters are used in health resort Jaunķemeri (together with bromine mineral waters) and in sanatorium Dzintarkrasts. These waters are extracted from springs or shallow wells. Baths of sulphuric waters increase body tone, improving the circulation of blood and metabolism. Internal use of sulphuric waters treats organ and tissue complaints, digestion and metabolism problems.

- Balneological Na-Cl brackish and saline waters from the reduced water exchange zone are exploited from hundreds of meters deep wells. These waters are used as table mineral waters and also for medical purposes both internally and for baths and water procedures. Depending on mineralization the waters are digestive and sedative, treats skin diseases, respiratory organs, bones, joints.

- The deeply lying Na-Cl brines with a high mineralization and bromine (up to 450 mg/l) content from the stagnant water zone are used as balneological waters at Liepāja hospital. This mineral water is the most concentrated in Latvia, thus the brines get used in diluted form for mineral-bathes which treats illnesses of joints and

Latvia

metabolism and strengthens neural system, or for inhalations during therapy of respiratory organs.

Threats and protection

Since the vadose zone of Latvia's hydrogeological system is rather thin and many deposits are characteristic of high permeability, freshwater resources in Latvia are naturally unprotected from the infiltration of pollution. Systematic groundwater monitoring in Latvia has been carried out since 1976. In some populated areas the overexploitation of fresh waters has stimulated the formation of depression cones; in places intrusions of saline waters also occur. On the national scale, ground water monitoring is performed by the State Ltd. "Latvian Environment, Geology and Meteorology Centre". In the case of pollution matters the commercial sector must observe subsoil quality under legislation. Meanwhile, the resources of deep-lying mineral waters are characteristic of a constantly high quality due to their natural protection by the thick overlying beds of low-permeability.

Myths or stories

There exist numerous legends concerning groundwater springs in Latvia related to the curative quality of waters (the Springs of health', 'the Cult springs', 'the Sacred springs', etc.), usually used for the treatment of eye and skin diseases. The miraculous properties of Baldone's sulphuric spring have assembled thousands of afflicted patients and vacationists through the centuries. Historical documents give evidences that the nobles of Livonia and Riga were resting and undergoing treatment cures at the sulphuric spring of Baldone or 'the Spring of juvenility' in the 15th century. The idea of organizing a spa near Baldone arose to Biron, oses. The sulphuric spring of Ķemeri is also called 'the Lizard spring' because its shape reminding a lizard. Its curative qualities have been famous since ancient times, and people from far and near were undergoing treatment cures there.

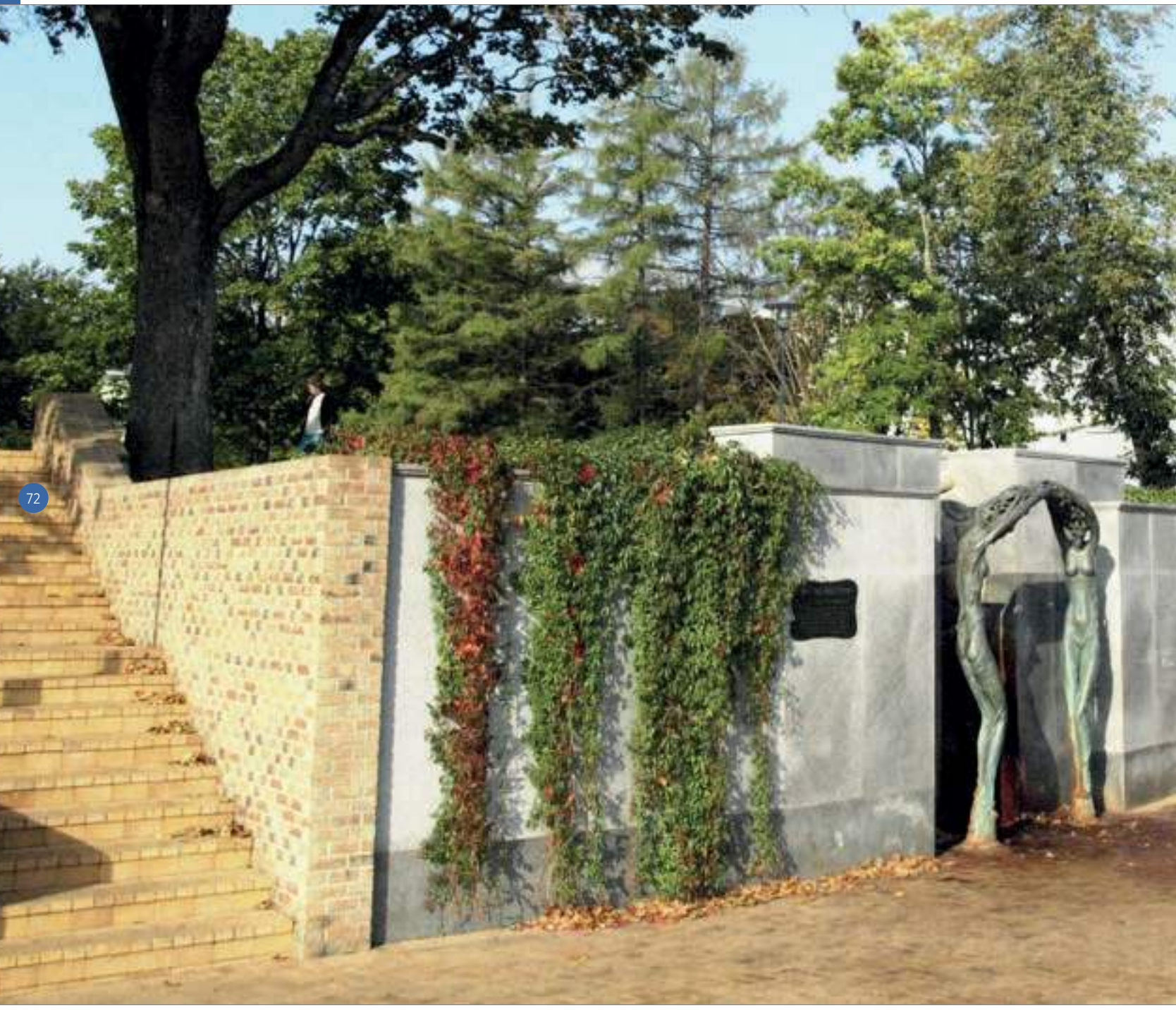
Curative powers are ascribed also to several freshwater springs like the King's Springs in Auce vicinity. They say that in the 16th century King Charles XII of Sweden got back his strength and health by drinking these waters. Other cult spring in Tirza village is also called the "Spring of life", the "Spring of health" or the "Holy spring". A legend tells us that the baron of Tirza did not like people visiting the spring and he ordered to fill it up. Once Baron did it, he lost his sight. Then he ordered to unearth the spring and started to make use of the spring water himself. Shortly afterwards Baron regained his eyesight.

Numerous legends tell us about springs flowing out of caves. The Gutman's (Good man's) Cave in Gauja National park is the largest grotto-type cave in the Baltics, and it still enlarges because of a freshwater spring flowing out of the sandstones. The local farmers used spring water for the treatment of diseases in exchange for gifts already in the 18th century.

Latvian Environment, Geology and Meteorology Centre

LVĢMC

Daiga Pipira is a geologist and head of Geology Division in State Ltd 'Latvian Environment, Geology and Meteorology Centre'. She was awarded a PhD in Bedrock Geology at University of Latvia. Daiga also is a researcher of University of Latvia in industrial minerals.



Lithuania

Introduction

Lithuania is rich in mineral water. In particular, South Lithuania is famous for its mineral waters. As this has been known for some time, resorts are located in Druskininkai and Birštonas. In written sources, Druskininkai was first mentioned in 1635. Mineral springs have been known there since the 18th century. Here, therapeutic activities were begun by local doctor Pranas Surutis (Surutis in Lithuanian means in The Salty). He warmed salty spring water in large vats, then filled small bottles and used them for healing of the sick.

After learning about the mineral springs, in 1789 King Stanislaw August Poniatowski visited Druskininkai and ordered the mineral water's properties investigated, but this order went unfulfilled. On 20 June 1794, King Stanislaw August Poniatowski declared Druskininkai a health resort. Russian Emperor Nicholas I signed an analogous decree in 1837.

By 1908, there were as many as 19 sources at Druskininkai, but only a few were mineral waters suitable for medical purposes. Later, some sources disappeared, while others opened in different places by themselves or via drilled wells. These springs' flow rates and degree of salinity varied. Today only one spring spews out, and is known as 'Grozio' (Beauty) spring.

For a long time at treatment resorts, natural springs of mineral water with salinity of about 1 g/l were used. In baths, salinity was increased by adding mineral concentrates obtained by evaporation of water. When sources dried up or did not meet their growing capacity needs, drilling of wells started.

In 1930 in Druskininkai, the first well was drilled for mineral water and its salinity varied from 6.7 to 8 g/l. Today, there are more than 20 wells of different depths that natural mineral water is abstracted from. The higher salinity water is used for balneology purposes in five SPA.

Why it is special and why it is good for our health

Druskininkai mineral water is rich in chlorides, sulphates, sodium, calcium and magnesium. We also find high concentrations of iodine, potassium, boron and lithium, which are vital to people. Mineral water is used to treat chronic gastric inflammation with reduced gastric acidity, gastric and duodenal ulcer (non-acute), chronic inflammation of the colon, chronic constipation, the initial stages of chronic hepatitis, gallstones, some of the urinary disease and kidney stones (postoperatively), metabolic disorders and diabetes (mild form).

Mineral water regulates acidity of gastric juices, antispasmodic, secretion stimulation, anti-inflammatory, regulates metabolism and has other therapeutic effects.

Externally used mineral water for treatments has long been regarded as one of the most effective health, stress relief and body-care techniques. Mineral water is a complex natural structure with up to 70 different items. Each centimetre of our skin has dozens of pain, heat and pressure-sensing receptors and approximately 200 thousand capillaries. Mineral water, acting on these points, treats various systems in the body.

Treatment with mineral water is not only excellent for diseases and a measure for their prevention, but very pleasant and relaxed. Relaxing the muscles of the body, psychological stress fades away, so after mineral water we feel well rested.

Lithuanian legislation identifies the Ministry of Health as the responsible institution for stipulation of the use of mineral water for health promotion.

Water resource distribution

For more than 100 years, Druskininkai health resort used mineral water abstracted only from drilled wells. A hydrogeological survey was conducted in 1972-73. After investigations, available mineral water resources were approved. Today, the resort can use 112 m^3/d of low (3.8 to 5 g/l, Q and K2 aquifers), 720 m3/d average mineralization of drinking-curative water (6.5 to 7.4 g/l, K1+K2cm aquifers), 1870 m^3/d of average mineralization (13.3 to 14.1 g/l, K1+K2cm aquifers) and for treatment procedures in baths, 70m^3/d of high (more than 35 g/l, T1 aquifer) salinity water.

It was found that the mineral water source is of the hydroinjection type, formed in the upstream migration of high-salinity groundwater from deep layers via tectonic fault zones. Such a water body is very sensitive to any changes in hydrodynamic conditions. Its resources are assessed in terms of mineral water and fresh water waterworks interoperation mode.

Currently, fresh water and mineral water extraction in Druskininkai is increasing. As one could expect, it makes a significant impact on the formation of mineral water conditions. The water salinity of three types of investigated mineral water and the concentration of major ions have gone up from 1.5 to 2.5 times.

In addition, some effects began to appear when new water suppliers started operating new mineral water wells. Due to this, some signs of the contamination of groundwater, posing a threat to deeper lying aquifers of mineral water, began to emerge.

In Lithuania, the Quaternary and Cretaceous aquifers usually contain fresh groundwater. The unique Druskininkai hydroinjection body occupies a relatively small area. Similar hydrogeological phenomena are also known in a few places in south Lithuania (such as the Birstonas, Liskiava and Stakliskes resorts, where the springs have 1,5 – 2,5 mg/l dissolved salts, respectively).

Threats and protection

At the national level, Governmental Decree No. 343 defines protection zones for resorts and safeguard zones for fresh and mineral water wells. Resort protection zones consist of three bands: the first – strict regime, the second – restrictive, the third – observation. The first band covers the areas in which mineral water, curative mud or peat deposits

Lithuania

and other therapeutic and recreational natural resources (rivers, lakes, sea, beaches and dunes) occur. The second belt comprises areas in which surface and ground water flow towards mineral water, mud and healing peat deposits and other natural healing resources. Its restrictions depend on the area surrounding the natural mineral water, be it mud storage, sanatorium territory, new sanatoriums or other resort building construction sites adjacent. The third band covers other resort-surrounding areas wherein activities that can have a negative impact on the therapeutic and natural resources and recreational resort hygienic status are forbidden.

Each band contains a list of restricted activities and facility construction.
The main threats to injection-type mineral water bodies are as follows:

- groundwater pollution from surface objects or resort infrastructure (roads and deicing salts used in winter, sewage network, drainage, etc.)
- overexploitation of resources that could disturb the hydrodynamic and hydro-chemical aquifer regime, leading to mineral water chemical composition changes
- drilling of new wells or installation of geothermal systems in vertical wells that could lead to the mixing of water from aquifers with different salinities.

Lithuanian legislation authorizes the Lithuanian Geological Survey as the responsible body for evaluation and approval of groundwater resources, collection and processing of monitoring data, and issuing permissions to abstract groundwater and geothermal energy.

Myths or stories

In ancient times, the times of the paganism (before Christianity), on a high and steep bank of the Nemunas, there was the famous Liskiava castle. Once, the ruler of this castle with his servants decided to go to hunt to other side of the Nemunas. Hunting was successful and to thank the gods for this, the prince had to shoot a falcon. When everyone had gathered on the banks of the Nemunas, the falcon was released. The prince shot the bird and it fell into the Nemunas. The prince fell into the water and dived. There was a commotion, everyone thought that the prince sank.

The most frightened and sad was the princess. She ran along river shore, cried for her husband plaintively, shedding salty tears. After some time, out of the water with the falcon in his hands appeared the prince, healthy and alive. In places where the princess' tears fell, salty (mineral) springs gushed from the ground.

It is now believed that the name Druskininkai could arise not only of salt mineral water, but also from a generic term, Saltman (engaged with salt-related activities or business), which is quite rare.

Lithuanian Geological Survey

Dr. Kestutis Kadūnas is head of the Hydro-geological Division at the Lithuanian Geological Survey. He is responsible for management of state groundwater monitoring systems, resource mapping and evaluation and groundwater pollution investigation. He has worked on the transposition of legislation directives 2000/60/EC and 2006/118/EC into Lithuanian law, and is a member of the Water Resource Expert group for EGS.

Dr. Jonas Satkūnas is a geologist, deputy director (1994-2014) and director of Lithuanian Geological Survey (since 2014). His interest is the investigation and promotion of geological heritage.

Macedonia

Introduction

Besides its natural beauty, cultural and historical, archaeological and geological heritage, the complex structural lithology construction, intensive tectonics associated with faults and fault zones in the Republic of Macedonia present a favourable environment in which aquifers of underground mineral, thermo-mineral and thermal waters are well established.

In terms of the potential with thermo-mineral and thermal waters, greatest significance is in Neogene and Quaternary magmatism, mainly expressed in the territory of the Vardar Zone and the Serbo-Macedonian massif. As for mineral waters, we can say that they show up throughout whole territory of the Republic of Macedonia.

From hydrogeological research conducted on the territory of the Republic of Macedonia, more than 25 locations are registered with potential thermo-mineral and thermal waters of a temperature greater than 21°C, with a total estimated yield Q>500 l/s.

Most of the thermo-mineral and thermal waters are used for heating, balneology and energy. According to statistics, thermo-mineral and thermal waters contribute 0.4% of total energy production in the country.

Thermal, thermo-mineral, mineral and groundwater for drinking in the territory of the Republic of Macedonia occupy a more significant place in overall development, primarily in terms of their energy use, water supply and commercialization (i.e. bottled drinking water)

Why it is special and why it is good for our well-being?

Everywhere in our country the notion of 'groundwater' is associated with the water supply, but ground water with increased mineralisation and temperature, despite drinking is used to heat greenhouse production, industry, spa centres, for tourism and to generate energy. Mineral and thermal waters in Macedonia were known for their curative (therapeutic) effects since the time of the ancient Greeks and Romans, and during the Ottoman Empire. Nowadays, its increased interest for development of spa tourism, owing to people's needs for recreation and relief from stress caused by the modern lifestyle. Saturation of the water with the presence of I, S, Cl, Br, Se, Li and radioactive elements ennobles the same with healing properties.

Water resources distribution

Significant localities with thermo-mineral and thermal waters in the Republic of Macedonia that are used in balneology are:

1. Bath Bansko (Strumica) was once a Roman bath, a healing place of antiquity, where in an area of 1000 m^2, were discovered ten small rooms on the east and west sides, in which are also higher rooms. The baths had dressing rooms, saunas, and swimming pools with hot, cold and lukewarm water.

   The bath used the thermo-mineral waters from spring 'Parilo', which is located 50 meters south of it. The bath probably dates from the 3rd century, the time of Roman Emperor Caracalla (211-217), who was withdrawing and restored baths throughout the empire. It is noted that in the second half of the 18th century and beginning of the last century the Turks began to build a bath in Bansko, then renovated the pool which exists today ('Yeni Ovlet' which means 'New Pool'). In 1920, two brothers from Strumica renewed the bath and built facilities for accommodation. In current conditions, thermo-mineral water is caught in a well with a capacity of Q = 50 l/s., temperature tv = 72 °C, while the macro-component composition is of the (Na+K)/SO_4 type, alkaline and nitrogen water that contain rare minerals. Thermal water is used for rheumatic diseases, respiratory problems, digestive problems, nerve disorders, gynaecological diseases, etc.

2. Banjiste and Kosovrasti-Capa (Debar) is centre for rehabilitation, recreation and relaxation in Debar, the western part of the Republic of Macedonia, which had earlier been used by the Turks. Exploitation of thermal water is from two springs:

   - lower pool (iron pool), a constant source with variable capacity Q=30-36,0 l/s and temperature of the water tvmah=39 °C

   - new catchments (Gorna Dere), occasional spring (the spring has water during March, April to June), with variable capacity Q=30,0-36,0 l/s with temperature of the water tvmah=35-38 °C. By chemical composition, in terms of the macro-component composition, thermo-mineral water is Ca-(Na+K)-Mg/SO_4-HCO_3, with presence of trace elements which give the water healing properties.

3. Kezhovica (Stip) is a city bath that has been used since Turkish times. Water is caught with an exploitation borehole at a depth of H = 60 m in granite, with capacity of Q=1.5 l/s and water temperature of tv= 57 °C. So far, from performed hydro-geological research, we can say that this locality has larger amounts of thermo-mineral water. According to macro-component chemical composition, thermo-mineral water belongs to the (Na+K)/Mg-Cl type, with low radioactivity, which impacts favourably on the human organism. It is recommended for neuralgic diseases and sciatica due to the specific affinity of radon to nerve tissue, with positive effects during illness on the gallbladder pathways, endocrine illness and especially the reproductive glands

4. Negorski Baths (village Negorci-Gevgelija), was used in Roman times. It is considered that Shukri Pasha first began to use them at that time and built two pools on the springs for bathing. Spring 'Hot Bath' is with capacity Q=0,35 l/s and temperature tv=40 ° and spring 'Cold Bath' has same capacity Q=0,35 l/s with a temperature of the water tv=38 ° . $NaSO_4$ dominates the composition of the water. In current conditions, several exploitation wells were bored, in which thermal water has a capacity of Q>15,0 l/s. Modernization of the facilities was done because of the healing properties of the mineral and thermo-mineral waters. They are used for needs in health, recreation and drinking.

Macedonia

5. Bath Katlanovo (Skopje) is one of the most famous Macedonian bath centres, which had earlier been quite often used by the Romans and later by the Turks. The surroundings of the bath include several hot and cold mineral springs, while the bath is supplied with water from an exploitation borehole, at a depth of 84 m, with capacity Q=4,0-5,0 l/s and temperature of the water tv=54 °C. Macro component chemical composition is (Na+K)-Ca/Cl-SO_4-CO_3 in type. Many types of rheumatic, kidney, nerve and diseases (etc.) are treated in the bath.

Threats and protection

As elsewhere, sources of groundwater pollution are industrial, agricultural and urban waste water. So far, only a smaller amount of urban and industrial wastewater is treated, but in recent years it has been growing steadily. The purpose of the protection of groundwater is human health and the environment, which in itself represents a concern for maintaining a good state of water, pollution prevention, and prevention of hydro-morphological changes and rehabilitation of the status of water in areas where it has been disturbed. Water management, as well as their protection in the Republic of Macedonia, is regulated by the Law of Waters, with secondary legislation arising from it, and also the obligations arising from the Water Framework Directive of the EU (2000/60/EC)

Myths or stories

1. Bath Katlanovo, in year 540 CE, when faithful general Belisarius approached Katlanovo, he had no great expectations. «Plague does not choose either by gender or by merit», he perplexed himself. When three months ago he had left his emperor, Justinian I, in the bathroom, he was half passed on the other side. That night when they called at the royal palace, he first saw the King as a man. Dark in the eyes and lips, just as could have been seen in patients in the poorest neighbourhoods of Constantinople, the emperor gave him a sign to approach. «Take me home», he whispered with grey lips, «If I can get well, I can only do so in Macedonia».

The road that devoted Belisarius had followed twice was not short. But it was nothing compared to how long he felt the path from the bridge of Pchinja to a wooden fortress on the bath. With helmet off, hands ready to take the heaviest burden, the royal crown which has to return to Constantinople,

Belisarius stood before the double-winged gate. When heavy shafts moved, morning sun broke from the other side and hit strongly in his face. As the gates were widening, so Belisarius spread his faith in the words of Justinian I: «Katlanovo is a boiler where the sun is born. If anything can cure me, it is there, between the sun and the water.» There, through the rock, earth and trees that melted under the morning rays, through water evaporation in boiling rock and rock in which water was boiling, he took in the whole splendour and immaculate masculinity, his master. Flavius Petrus Sabbatius Justinianus or Justinian I stood before him with open arms and a smile that said, «I told you!»

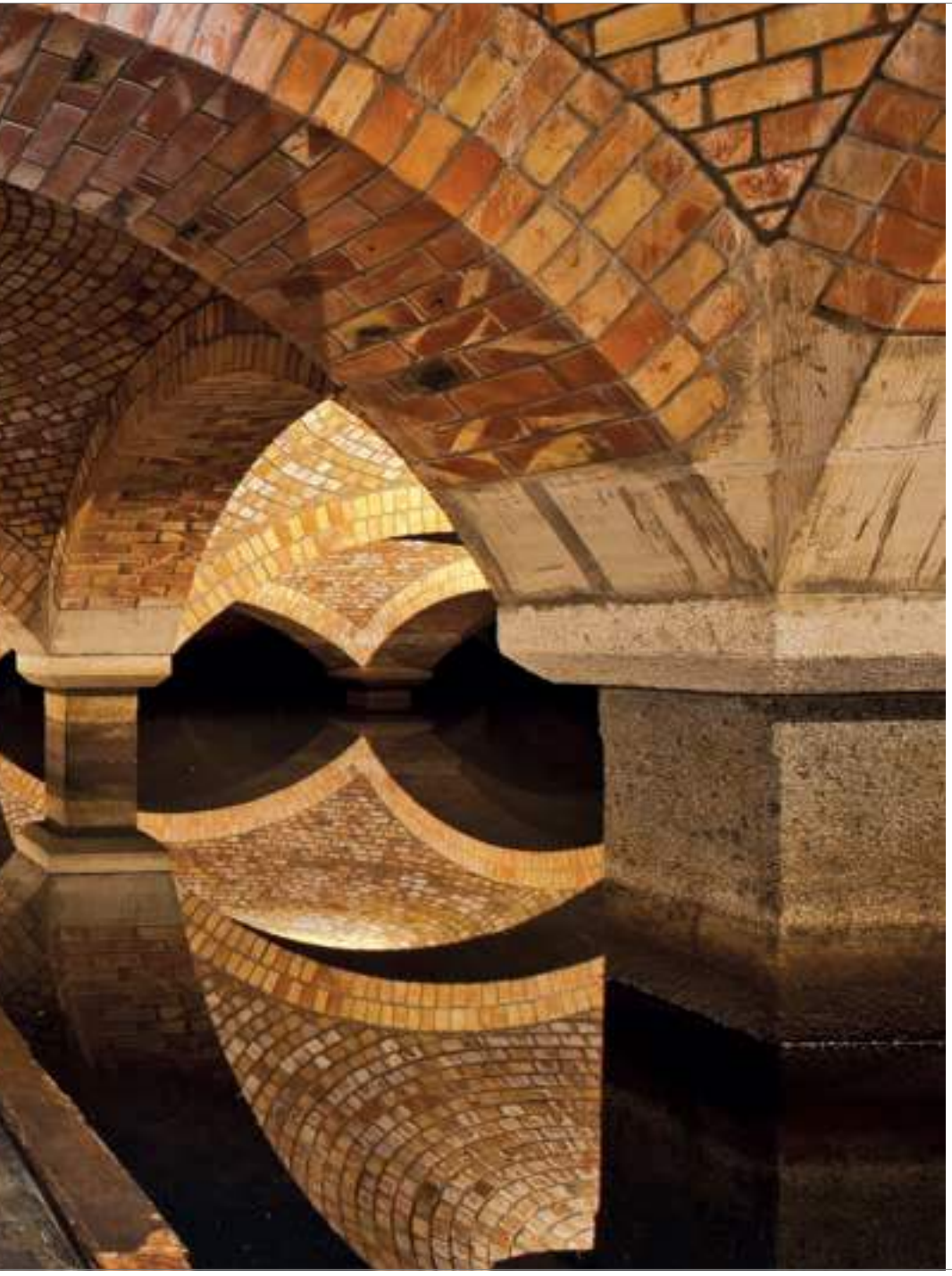
Geological Survey of the Republic of Macedonia

Kostadin Jovanov has an MSc in hydrogeology and is the director of the Geological Survey of The Republic of Macedonia. Previously, he worked on basic hydrological surveys, research for water supply needs, thermal mineral waters, mining and in the area of regulation of geological research in the Ministry of Economy of the Republic of Macedonia.

Ivica Mitev is geologist who works as a junior assistant in the Department of hydrogeology and engineering geology in the Geological Survey of the Republic of Macedonia.

Dejan Pavlov Pavlov is associate for geological research in the Department for geophysics and geothermics. Previously, he has worked on detailed geological, engineering-geological, geomechanical, and hydrogeological investigations and examinations.

Poland



Introduction

Groundwater resources of Poland are estimated as 13.6 km^3, mainly in the Quaternary aquifers and are considered as a fraction of total volume of meteoric water infiltrating into groundwater-bearing zones over a year. The total amount of fresh groundwater in Poland, meaning the water volume gathered in aquifers, is estimated as 5000 km^3 and only in a small friction is polluted with substances introduced by humans. For comparison, the river discharge to the Baltic Sea from Polish coast does not exceed 56 km^3 in an average hydrological year. Water resources gathered in rocks are over 100 times higher than surface water resources gathered in rivers, lakes and other surface water reservoirs.

By groundwater resources we define a groundwater volume that can be continuously exploited by water intakes for drinking, agricultural and industrial supply, considering all local ecological needs at the abstraction area. Disposable resources (safe yield) are defined as the maximum and guaranteed abstraction of water volume from an aquifer without pointing at a specific abstraction point. The concept of sustainable development and ecological rule of groundwater management requires a part of safe yield to be left for sustaining ecological needs, including flora and fauna.

Groundwater is economically very valuable, as it usually does not require complicated and expensive treatment and steady chemical characteristics along the year. When occurring underneath a series of low permeability layers, it is well protected from surface pollution.

Why it is special and why it is good for our well-being?

Poland is rich in groundwater resourses, opposite to surface water resources. The municipal water supply comes in over 70% from water intakes based on the aquifers. The total use of groundwater for municipal supply in Poland is less than 1.5 km^3 a year.

Taking into account the EU Framework Water Directive, the necessity of considerable changes in water management, water resources protection and water status reporting, an idea was put forward to organise Polish Hydrogeological Survey (PHS) in 2002. This Survey was established on the Water Law Act of 2001. The fact of delegating the state duties as regards groundwater to an unit established specifically for this purpose, shows the high rank of hydrogeology in the field of Earth Sciences. It also reveals the significance of groundwater resources for the society, economy and for protection of groundwater-dependent terrestrial ecosystems.

PHS activities are being successfully implemented, mainly due to structural and organisational changes, such as the establishment of Polish Hydrogeological Survey at Polish Geological Institute – National Research Institute.

The 21st century brought new challenges to hydrogeology, especially:

- During droughts, excessive exploitation of groundwater resources can be observed, while shortages of water occurs also in periods of prolonged downpours. In the last 15 years, we have experienced 3 enormous floods

- The retained groundwater resources can be of particular significance during emergency situations in the country. During the hazards, the country could be supplied with drinking water from the groundwater intakes only,

- In the last decade, problems of both temporal and spatial scale have become increasingly evident. Groundwater flow modelling results at a regional scale give approximate outcomes, most often for steady-state conditions. Data for models come from on-the-spot studies of hydrogeological conditions carried out from the well tests or from laboratory tests.

- another challenge for groundwater resources protection is the increasingly frequent use of renewable energy sources (RES). The largest geothermal water resources in Poland occur in Mesozoic aquifers. Geothermal waters have been stated at depth of over 1500 m in sandy forms of the Lower Cretaceous and Lower Jurassic strata.

Along with numerous scientific institutions and geological companies, the Polish Hydrogeological Survey documented the Major Groundwater Reservoirs. These works help to determine the most perspective resources and to protect zones of the drinking waters reservoirs in Poland, that are also an alternative source for current water supply and apply to future generations.

The tasks of the Polish Hydrogeological Survey

These tasks under the Water Law Act can be grouped in several sections:

I. Groundwater measurements and observations

The Polish Hydrogeological Survey organises and modernises the groundwater monitoring network, making possible its maintenance in a good condition for constant measurements, observations and research. The basic network has over 1150 points (primary and secondary hydrogeological stations) and is in co-operation with regional and industrial networks comprising additional 1000 monitoring points. Automatic measurement and data transmission equipment is installed in selected stations. Depending on the needs, The network's monitoring points allow for observation of the chemical and quantitative condition of the GWB.

The Polish Hydrogeological Survey prepares annual assessments and forecasts of groundwater conditions and hazards. This is possible through data collection in GIS databases and processing the information according to standard procedures (in conformity with the INSPIRE guidelines). The groundwater monitoring network's measurements data are kept in the database and are made available by PHS to State and municipal administration, and upon the consent of the data owners – also to commercial companies and private persons.

Poland

II. Hydrogeological data collection, verification and processing

Parameter data of aquifer masses, specific resources, potential discharge of intakes, quality and systems of groundwater circulation are obtained in the country during construction work of new intakes, searches for natural resources or specialised field studies. The output of hydrogeological observations and studies is very costly and cannot be conducted for one-time purposes due to financial reasons, e.g. for the purpose of assessing the condition of groundwater resources of GWB and river basins. It is therefore necessary to accumulate and verify the data in the hydrogeological databases, e.g. the HYDRO Bank, which has been under constant development for 45 years in the Polish Geological Institute. Another important database is the Hydrogeological Map of Poland in 1:50.000 scale, made as a digital serial map comprising of 1069 sheets, with total country coverage. The Groundwater Resources and Intakes databases contain periodically updated information to be used in regular assessments and forecasts of groundwater resources changes, prepared for people who make strategic decisions regarding the country's economy and population.

III. Publications, training, personnel qualifications and national standards as regards groundwater resources protection and use

Development of reports, announcements, balances and groundwater monitoring systems requires uniform procedures and techniques for measurements and field work, sample collection, data collection and processing. PHS takes care of the development of procedures and standard techniques for the country through publications, training and scientific workshops. For educational purposes and reports, assessments and forecasts, graphic representation of groundwater database results is necessary. It is developed through standard GIS systems, computer cartography and result visualisation methods for the decision-makers.

PHS disseminates and popularises knowledge on groundwater, its protection and use. Within the ecological education of society, the Survey approaches water resources as the environmental element necessary for ecosystems functioning. It is also available to get information in a digital version on the Ministry of Environment website and the official PHS website: www.psh.gov.pl.

Threats and protection

The resources condition and possibility of their use are also very important issues in case of emergencies. Reports containing groundwater resource balances are part of water management balances of regions, catchments and the whole country.

In case of failure of the water supply network, geohazards, terrorist attacks or chemical contamination of surface waters, groundwater resources are the only drinking water reserve for people. Strategic groundwater reservoirs and their protection are supervised by PHS. This Survey is also responsible for assessing the risk and studying the endangered area.

A map of areas endangered by flood in the valleys of Poland's main rivers was successfully and thoroughly verified during this year's flood. Prepared between 2003 and 2006, The Map of Areas in Danger of Being Flooded in Poland is an important tool assisting flood risk management in the country.

Polish Geological Institute - National Research Institute
Polish Hydrogeological Survey

Lesław Skrzypczyk is the deputy director of the Polish Geological Institute-National Research Institute, director for Polish Hydrogeological Survey affairs. He was awarded a PhD in hydrogeology in the Polish Geological Institute-National Research Institute. He is Vice President of the National Water Management Authority.

Małgorzata Woźnicka is a hydrogeologist, PhD, graduated from the Faculty of Geology, Warsaw University. Her responsibilities at Polish Geological Institute-NRI include performance of Polish Hydrogeological Survey in the area of appraisal, balancing and protection of groundwater resources.

NASCENTE PEDRAS SALGADAS

Portugal

Introduction

Portugal has several types of thermal and mineral waters, with different discharge flows, hydrochemistry characteristics and temperatures. Used in health and wellness, bottling industry and as a geothermal resource, they are recognized as exceptional due to their physical properties, chemical composition and therapeutic qualities confirmed by specialists. Mineral and thermal waters long ago became part of the popular Portuguese tradition and have been used for centuries in balneotherapy, mostly to improve the health and overall well-being of local communities. Documented use of mineral waters in Portugal dates back to the Roman occupation of the Iberian Peninsula, mostly due to their recognized healing properties.

In the 19th century, balneotherapy facilities were mostly attended by aristocracy and the upper-middle class. In fact, some of them turned into high society thermal resorts and gained national popularity, especially during summer time. On the other hand, other mineral waters had major local importance in the first half of the 20th century, where entire families joined every year as a community to benefit from them. Balneotherapy tourism has grown very steadily over the decades. Modern spas provide a large range of treatments, along with leisure activities, sports and amusement for all ages. Although traditionally mainly dedicated to senior health and tourism, nowadays, entire families make regular use of them during their summer vacations.

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Why it is special and why it is good for our well-being?

The first scientific studies of mineral waters in Portugal date back to the 18th century, with an exhaustive inventory made by the personal physician of King John V, in a 1726 book named *Aquilégio Medicinal*. Besides a classification, their main characteristics are described in this book, including their therapeutic use. While the mechanism of action of balneotherapy is poorly understood, the therapeutic benefits have long been recognized. Reflecting the consciousness of their health and benefits, as well as a genuine worry in controlling diseases and epidemics, the therapeutic virtues of mineral waters have also launched the bottled mineral water market, between the 19th and 20th centuries.

Nowadays, although the richness of the Mediterranean diet is internationally recognized by UNESCO, negative changes in regular dietary habits due to modern life turn mineral water drinking into a supplementary source of minor elements to be ingested on a daily basis to avoid health problems. Due to the popularity of the spas located throughout the country and their distinctive temperatures and chemical and physical elements, medical hydrology has become of major importance when choosing a spa and the specific treatments to be undertaken. The prescription of a wide range of treatments, ranging from drinking, breathing, bathing or mud-bathing at different temperatures, with specific equipment, increases the importance of mineral waters.

Use of the resource

In Mainland Portugal, more than 400 mineral or thermal springs with uneven geographical distribution are identified. Most of them occur in the north and central part of the country, in the Iberian Massif. These waters emerge predominantly from granitic and schistose rocks, usually associated with major regional active faults. The most abundant type is sodium sulphur water, characterized by the presence of reduced forms of the sulphur ion, high silica and fluorine ion content and usually pH above 8. Water temperatures range from 20 °C to 69 °C (S. Pedro do Sul) and Total Dissolved Solids (TDS) can often reach 1000 ppm. Another common type is the sodium bicarbonate CO_2-rich mineral water, which is widely bottled and sold, and whose occurrence is confined to northern Portugal. These waters have TDS that go up to 2500 ppm, CO_2 levels that range between 500 and 5000 ppm and pH values ranging from 5.9 to 6.7. Water temperatures are typically below 20 °C, but in Chaves they reach 76 °C.

On the other hand, the Western and Southern Mesocenozoic Sedimentary Basins, mainly composed of sandstones and limestones, originate mineral waters with higher discharge flows, more mineralized, typically sodium chloride bicarbonate and, to a lesser degree, calcium sulphate waters with a pH close to 7 and water temperatures ranging between 20 °C and 40 °C. These springs are usually related to active fault systems, a halokinetics, or both. The presence of salt diapirs strongly influences the water chemistry, usually causing a remarkable increase of sodium chloride and sulphate ions and to the TDS content, which can reach 3500 ppm.

In the Azores archipelago, consisting of nine islands of volcanic origin, there are more than 100 mineral water springs and thermal pools. Most of them are located in S. Miguel, but there are others in Terceira, Graciosa, Pico, Faial, Sao Jorge and Flores islands. The majority of Azorean mineral waters are related to active central volcanoes while other discharges are located on older volcanic structures.

The main uses are related to the bottling industry, geothermal resources in heating and cooling facilities, greenhouses, swimming pools heating and balneotherapy.

Threats and protection

Portuguese law defines a mineral water as bacteriologically pure, with stable chemical and physical characteristics resulting in favourable effects to health. It distinguishes mineral from drinking water in its original pureness, mineral contents and minor elemental characterization as well as deep groundwater circulation. Considering these characteristics, a good knowledge of the hydrogeological circuit of the mineral groundwater is of utmost importance to assure its quality. Natural Mineral Waters in Portugal are protected by the 1990 legal framework (D.L. 90/90 and D.L. 86/90), defining them as a 'geological resource'. This means that they are exploited under a legal concession regime that allows government authorities (Directorate General for Energy and Geology and Directorate-General of Health) to implement national policies close to the exploitation entities.

Portugal

The idea of defending and preserving mineral water as a non-renewable resource is the basis for this industry as a strategic framework. Therefore, only the noblest waters can be classified as mineral.

Special care is taken in natural mineral water quality monitoring and preservation. It is based on an Exploration Plan, a technical and scientific document that defines mineral water exploitation and use. Periodic physical and chemical analyses are also carried out by the exploitation companies, regularly reported to the government authorities. In the last decade, the national authorities encouraged a progressive replacement of primitive springs with equipped boreholes, crucial to preserve the quality and quantity of the available resources. The same 1990 legal package assumes the creation of three protection zones for the mineral water occurrences (enlarged, intermediate and closest protection zones), each of them following different rules but with increasing restrictions defined according to hydrogeological criteria. These zones intend to protect the mineral water resources by restraining the level and intensity of activity in sensitive areas, based on hydrogeological parameters and technical support constraints. This legal implementation is supervised by local and national authorities.

Myths or stories

Mineral waters were used in Portugal since the Roman and Arab ages. For instance, in Lisbon, the original Arab name of Alfama (*Alhama*), one of the most popular and typical districts in the city centre, means 'hot spring'. These very abundant hot mineral waters located in Alfama were used to supply the caravels that sailed towards the unknown seas during the age of Portuguese discoveries. Many economic activities related to water were also developed in Lisbon, as the Alfama toponymy and archaeological remains prove.

In several periods of Portuguese history, mineral waters also played a very important role. That is the case of the first King of Portugal, Afonso Henriques who was healed with S. Pedro do Sul sulphurous mineral waters (in the so called *Alafões*), for his broken leg injuries, suffered at the Badajoz Battle, in 1169. In the 12th century, Mafalda, Queen of Portugal, ordered the construction of an inn at Caldas de Aregos, which became the forerunner of thermal spa in Portugal. Also with historical importance, Caldas da Rainha was named after Queen Leonor, wife of King John II and founder of the Caldas da Rainha thermal hospital, in 1485. According to legend, the Queen was passing by and saw some poor people bathing in steaming waters considered by them as 'healing waters'. She then ordered the construction of a thermal baths facility and a thermal hospital, both lasting to the present day.

National Laboratory of Energy and Geology

Ana Paula Pereira graduated in Geology (1989) from the University of Oporto, is a hydrogeologist in the Department of Geology, Hydrogeology and Coastal Geology of the National Laboratory of Energy and Geology (LNEG), and an expert in hydrogeological mapping and Geographical Information Systems.

Elsa Cristina Ramalho graduated in Geological Engineering (1991) and has a PhD in Geosciences. In 1994, she joined the Hydrogeological and Geothermal Resources Department from the former Mining and Geological Institute of Portugal. Now, she works in the Mineral Resources and Geophysics Unit of the National Laboratory of Energy and Geology (LNEG). Her research is mainly focused in shallow and deep geothermal and geophysical methods applied to hydrogeology and mineral resources.

Republic of Srpska

Introduction

The territory of the Republic of Srpska, as one of two entities in Bosnia and Herzegovina, covers 49% of its territory (about 25,000 km2). Due to its complex geology, it was already regarded with interest for exploration in the Middle Ages, as one of the most important mining sites in Balkan Peninsula. Many German miners moved into the area and the first occurrences of mineral waters were registered. The territory mostly belongs to the Dinaric orogeny, and a smaller part to the Pannonian basin. Within the Dinarides, there is distinction between the External Dinarides (carbonate platform) and the Inner Dinarides (including a few subzones: flysch zones, zones of Palaeozoic rock, ophiolite belt, carbonate zone, etc.).

Geological distinction between the above-mentioned zones results in distinction in their hydrogeological characteristics. The External Dinarides zone is described as the homeland of karst, with an abundance of fresh groundwater and total absence of thermal-mineral water. The Inner Dinarides zone, especially the ophiolite belt zone, is characterised by an abundance of thermal and thermal-mineral springs, and smaller reserves of fresh groundwater than the first one, mostly restricted to alluvial intergranular aquifers. In the Pannonian basin, thermal-mineral waters have been discovered in the past, at depths of more than 1000 m beneath the terrain's surface.

Why it is special and why it is good for our well-being?

Generally, the main use of groundwater is for water supply. More than 75% of drinking water is provided from groundwater. The second important use of groundwater, especially in eastern Herzegovina, is for hydropower production. There are two hydro power plants in the Republic of Srpska based on karst aquifers, (average annual production over 10 years of 425 GWh), one in Croatia (mean annual production 1168 GWh) and one in the Federation of Bosnia and Herzegovina (mean annual production 400 GWh). Groundwater in the eastern Herzegovina area, traditionally sparsely populated in the south, plays a role of key socio-economic importance. Smaller amounts of groundwater are used for irrigation.

Thermal and mineral waters play an important role. There are six spas with thermal water and one with mineral water. Use of these waters varies from simple relaxation to proper medical treatment. The waters in these spas are very different in chemical composition. Some of them are slightly radioactive (Višegrad), some hyper-alkaline (Kulaši), and some contain specific micro-components, etc. The effects of their use are recognized on the skeletal, nervous and cardiovascular systems, etc.

In Petrovo, thermo-mineral water is used for CO_2 extraction. In Kozluk, mineral water is used commercially for bottling (Vitinka Zvornik). Both of these uses represent very important economic activities in the regions where they operate.

Water resources distribution

The Republic of Srpska is a very rich country in fresh and thermo-mineral waters. Generally, there are two hydrogeological regions coinciding with its tectonic division. In addition, a review of the resources should be undertaken for the Inner (about 80% of the RS) and the External (about 20%) Dinarides. The Inner Dinarides has its biggest reserves of groundwater in the sandy-gravel sediments of the biggest rivers (Sava, Una, Sana, Vrbas, Bosna, Drina). These reserves exceed 10 m^3/s in flow.

There are also areas with important karst aquifers. The most important karst aquifers are within the limestone of Mt Romanija and Mt Devetak in the east of Srpska (the minimum discharge of their springs is more than 4.5 m^3/s). Karst aquifers exist in the western part of the entity as well, in limestone at Mt Manjača, Mt Vlašić, Mt Klekovača, etc. In the transitional zone between the Inner and the External Dinarides, in the western part of Srpska, the Pliva, Janj, Sana and Ribnik springs emerge, with a total minimal discharge more than 10 m^3/s.

Thermal and mineral springs occur mostly in the ophiolite zone, extending overall from the east to the west of Srpska. Višegrad thermal waters are slightly radioactive. There are numerous springs and three wells with yields of 70 L/s (32 °C). In the central part of ophiolite zone, three localities with thermal water exist: Petrovo (39 °C), Teslić (39 °C) and Kulaši (30 °C). There are also three localities with thermal waters close to the capital of the Republic of Srpska, Banja Luka. The wells in Slatina village have the highest temperature (43 °C), with reserves greater than 100 l/s. Similar to the thermal water of Petrovo, the CO_2 content and mineralisation are very high. In the other two localities, mineralization is significantly lower (up to 1 g/l). The most western occurrence of thermal water is Lješljani. The spring has a temperature of 20 °C and a well (672 m deep) at 30 °C with a yield of 7 l/s.

During unsuccessful oil exploration in Semberija (the southernmost part of the Pannonian basin, belonging to Srpska) thermal waters were found in limestone, at depths more than 1000 m, below a thick package of tertiary sediment. The well in Slobomir yields about 40 l/s at 75 °C.

As was mentioned, the External Dinarides in the Republic of Srpska extend thru the whole eastern Herzegovina region. It is an area with highly karstified limestones and the area that some of the most important karstologists in the world, like Jovan Cvijić, call the homeland of karst. There are some of the biggest karst springs in the world, with high fluctuation in discharge (for springs of the Trebišnjica river, the ratio of minimal and maximal discharge is 2:800 m3/s), the biggest European sink river (Trebišnjica), and impressive swallow holes (Ponikva, Pasmica, Ključki ponor, Srđevići) with capacities of a few m3/s. One of the main characteristics of karst aquifers in this zone is a wide fluctuation in water levels depending on the precipitation regime. Registered changes of the water level in observation borehole Z-3, in Nevesinjsko field, is 312 m over 183 days.

Republic of Srpska

Threats and protection

The status of groundwater in the Republic of Srpska, Bosnia and Herzegovina is generally good. There is no significant decrease in the groundwater levels of porous aquifers or of spring yields. Regarding the water quantity, a small number of towns in Srpska have problems. Unfortunately, a high rate of water pumping is frequently related to high waterworks losses. There are two important facts affecting good-quality status of groundwater. The first one is a thick protection clay layer of porous aquifers (3-5 m), and the second one that the catchment areas of karst springs are very sparsely populated. Turbidity and bacteriological contamination are common quality problems. The first one is mostly triggered by forestry exploitation, the second one by inadequate waste water release. Problems caused by agriculture, regarding a high level of nitrates, are not reported.

The rule on sanitary protection zones (Official Gazette RS 07/03) offers a good base for drinking water protection, but it has not been applied enough in praxis yet. Despite the fact that large numbers of drinking water sources have established sanitary protection zones and protection measures, there are many violations of protection measures without consequences.

The weakest point for sustainable use of groundwater is monitoring. After 1992, it was totally neglected and its improvement is one of the key recommendations in the documents dealing with integrated water management.

Myths or stories

"Water is sometimes equal to gold," someone said. It sounds like a bad comparison. Nevertheless, four years ago, I began to think about it. It had happened during the meeting in the European karst homeland, in Trebinje town. The area is well known not only for its beautiful karst landscapes, but also for very high precipitation (average about 2000 mm/year). I drove six hours from my hometown and reached the hotel about 6 pm. For the next hour, I could not take 10 steps between my car and the hotel because rainfall was extremely intense. When I finally entered hotel reception, I met my colleagues who had come several hours ago and started to complain about the strong rainfall. An old man, probably some auxiliary worker in the hotel, told me: "Boy, would you come here today if rainfall did not fall in the past like today?" I looked at him a little confused. He continued: "Fifty years ago, we considered leaving this area. But possibilities for poor people were very restricted. In that moment, as we began to consider the best way of utilising this rain, our problems were solved. Two dams, two big reservoirs, four power plants and this rainfall became gold for us. We have provided enough water for drinking, irrigation, electricity generation, for future life, and for our children, for everything. When we have weather conditions like today, we are fully aware that a better tomorrow is safe." I understood. One should always look on the bright side of rain.

Geological Survey of the Republic of Srpska

Boban Jolović is a Hydrogeologist, head of the department for GIS in the Geological Survey of Republic of Srpska, Bosnia and Herzegovina. His research focuses on groundwater utilization and protection, especially in karst areas. Boban is also a former member of the group for groundwater within the ICPDR project, a member of the groundwater group within UNESCO MedPartnership project. He is one of the key experts for hydrogeology in the GEF project (acronym DIKTAS), the first ever attempted global introduction of sustainable integrated management principles in transboundary karst aquifers on the magnitude of the Dinaric Karst System.

Romania

Introduction

Romania consists of four major areas of Mesozoic and older rocks: the southern Carpathians, eastern Carpathians, Apuseni Mountains, and Dobrogea. Late Tertiary sedimentary rocks occupy areas among these four regions and overlie older rocks in the Pannonian basin, Transylvanian basin, Skythian (Russian) and Moesian platforms. Although the Carpathian orogenic belt appears to be a continuous easterly arc through Romania, this belt is formed through a series of events, that began in Triassic time and continue to the present.

As a consequence of the prevailing presence of impervious rocks against permeable ones, groundwater has a varied territorial distribution. The tectonic and breaking degree of the impervious formations, presence of tectonic depressions and calcareous massifs favor groundwater important accumulation. In the Carpathian areas, important resources of deep waters are reported in synclines, Mesozoic limestone and conglomerates, Cretaceous-Paleogene flysch, and in the volcanic-sedimentary formations.

In the Carpathian area, by fragmentation, steep slopes, and an active drainage regime, phreatic waters are spread unevenly, in the cover deposits, and in the fissures of rocks (sandstone, conglomerates, eruptive).

Why are these waters special and good for our well-being

In Romania, besides normal drinking waters, other types of groundwater can be mentioned: mineral, and geothermal. The drinking groundwater has a rather irregular distribution in the Carpathian area, being in close connection with the hydro-structure type: alluvial, tectonic, and karst depressions, etc. The intermountain tectonic depression type is prevalent in the Eastern Carpathians, where waters are under pressure, when they are intermingled with impervious layers. Karstic hydro-structures are more frequent in the Southern and Western Romania, many of them being important water supply sources for urban agglomerations.

There are about 500 localities, having over 2,000 mineral springs in Romania. The main hydro-chemical types are: sodium-chloride, iodide and bromide, sulphuric-sulphate, and carbonated water. These carbonated waters are closely linked to Neogene volcanism, the carbon dioxide being a post-volcanic product in so-called 'mofette halos', which are found mostly in the Eastern Carpathians.

In terms of hydro chemical type and thermal gradient, mineral waters are used for internal and external spa-cures and are bottled as drinking water for consumption in Romania and abroad, in many localities such as: Borsec, Biborţeni, Bodoc, Zizin, Şarul Dornei, Poiana Negri, Tuşnad, Sîncrăieni, Căciulata, Slănic-Moldova, Hebe, Covasna, etc. At present, 25 mineral deposits with 30 auxiliary bottling plants are in exploitation.

The thermal waters have been used even since the Roman Empire period for balneal treatment. The presence of mineral and thermal waters has resulted in setting-up of many balneo-climateric health resorts in Romania, such as: Baile Herculane, Sovata, Calimanesti – Caciulata, Baile Govora, Baile Tusnad, Ocnele Mari, Baile Felix, Baile Olanesti, Geoagiu-Bai, Buzias, Vatra Dornei, Ocna Sibiului.

Uses

Due to geologic structure, Romania has important resources of mineral waters, dominated by carbonated natural mineral water. In fact, Romania holds almost 60% of mineral water resources of Europe, but only 20% of these mineral resources are being exploited.

Over 45% of natural mineral water accumulations are related to carbonate rocks – limestone, calcarenite, conglomerate, followed by andesite and pyroclastic rocks (around 25%), in sedimentary detritus deposits (approximately 25%), and crystalline schists (5%).

Romania offers wide opportunities for relaxing, and is well known for its thermal waters, lakes and wellness treatments.
In Romania, there is one of the most famous ancient resorts, called Baile Herculane, well known even in Roman Empire times. Its first attestation is from year 153. Beginning with 1736, during the Austrian period, the resort developed a lot. Most of the important edifices from the resort, influenced by an impressive Austrian baroque style, have been built. Many important people who enjoyed the therapeutic virtues of thermal mineral waters have visited the spa along the time. One of its visitors from the Roman times was Emperor Marcus Aurelius with his mother Iulia. From the Austrian period, we mention the Emperor Franz Joseph who visited the spa together with the Empress Elisabeth (Sissi). In 1852, Franz Joseph considered Baile Herculane the most beautiful resort in Europe. According to legend, even the ancient Greek hero Hercules stopped here to take a bath and to relax.

Three main geothermal areas, having three types of structural-geological units, extending to the neighboring countries, occur in Romania.

The first type includes platform regions that, after the Assynt, Caledonian and Hercynian orogenies, lost their mobility as geosynclines. This category contains the East-European Platform, Scythian Platform and the Moesian Platform. Being very old units, their crust is thick (45-50 km) and rigid, with a heat yield of 1.1 cal/cm^3/s. In their case, main emissive segments for the radiogenic heat are concentrated linearly around trans-crustal fractures, or on remobilized tectonic basement areas. In the first category, important geothermal resources are Mihai Bravu - Insuratei sector, on the Capidava - Ovidiu fault, and North Bucharest - Otopeni - Snagov sector. The second category includes the Optasi - Bals - Slatina structural uplift, with segments affected by rift genesis and bimodal magmatism (acid and basic) between the Triassic and the Permian. Over almost 100 km^2,

Romania

the Upper Jurassic-Lower Cretaceous limestone aquifer, situated at 1,600-2,300 m depth, has water resources with a surface temperature of 60-75 °C.

The second type of structures is represented by a geological region, active in the last two eras: the Carpathians. In the Carpathians, the main geothermal areas are the result of:

a) disintegration of radioactive elements inside the granite masses, possibly of Tertiary age (Herculane Spa);

b) some important tectonic events, such as Southern Carpathian thrusting from the end of the Upper Cretaceous (Calimanesti - Caciulata);

c) thermal remnants of the Neogene - Quaternary volcanism in the Southern Apuseni and western Eastern Carpathians.

The third type is composed of the great post-tectonic depressions. They contain big parts of the alpine orogen at a depth of 2,000-3,000 m, covered by an Upper Senonian - Holocene sedimentary pile. This category includes the post-orogenic Transylvanian and Pannonian basins, that have a distinct compression tectonic regime. The Transylvanian Basin has a thin crust (30 km), implicitly a thin granite layer (12 km), a low thermal flux (40 mW/m^2) and a heat yield of 1.72 cal/cm^3/s.

The Pannonian Basin, of the same crust thickness, has a heat yield of 2.4 cal/cm^3/s, an average thermal flux around 95 mW/m^2, and temperature gradients of 50-70 °C/km. So, between the towns of Satu Mare and Timisoara, geothermal fields are found in Pannonian siltstones, with water resources of 50-105 °C surface temperature. The most important mineral water resources of this depression are the geothermal waters billeted in Triassic - Cretaceous fissured limestones (flow rate 400 l/s at about 70-105 °C).

Threats and protection

Globally, water is a renewable natural resource, but vulnerable and limited, so it must be treated as a natural heritage to be protected. In our century, one of the largest global problems concerning water management, taking into account that the population of the planet, who is in continuous growth, is the crisis of drinking water.

Water resources in Romania were evaluated as a potential of around 136 billion cm/year, of which: around 40 billion cm/year of the Romanian catchments, 87 billion cm/year of the Danube's (available for water use, around 30 billion cm/year) and around 9 billion cm/year from groundwater (only 6 billion cm/year economically useful).

The total groundwater exploitable resources are evaluated as follows: 3 84.2 m^3/s (Institute of Geology - Geophysics - 1988). The exploitable balance resources, satisfying quality and technical-economic criteria go up to 304.9 m^3/s , out of which: 149.4 m^3/s from phreatic; 155.5 m^3/s from deep groundwaters.

With respect to geographical repartition, the exploitable balance resources (304.9 m^3/s) are distributed as following: Western plain, North from Mures river - 38 m^3/s (12.5%), Banat plain - 26 m^3/s (8.5%), Transilvanian plateau - 25 m^3/s (8.2%), Moldavian plateau - 35 m^3/s (11.5%), Romanian plain – 137.5 m^3/s (45.1%), Danube wetlands and terraces (including Delta) - 29 m^3/s (9.5%), Dobrogea – 14.4 m^3/s (4.7%).

Myths or stories

Water is a magical element in Romanian fairy-tales which one finds in two forms: living water and dead water. Through water, the fairy-tale heroes experience the miracle of death and resurrection. In Romania, according to the legend of Master Manole, the sacrifice of the artist during perfecting of his work, has, as a testimony, a fountain that 'sprung out of tears', in front of the Monastery Curtea de Arges.

Geological Institute of Romania

Diana Persa, is a hydrogeologist, who worked at 'Romanian Waters' National Administration. Now is a researcher at Geological Institute of Romania. Her research focuses on water management. She is also member of the Eurogeosurveys Marine Geology Expert Group.

Russia

Introduction

Russia possesses vast groundwater resources confined to different (in age and genesis) hydrogeological structures. The area of federal interests mainly includes potable and mineral water, meeting the current and future needs of the Russian population, as well as thermal waters. Fresh groundwater is the most reliable source of high quality drinking water supply, protected from contamination from the surface; therapeutic mineral waters are an affordable and effective treatment and preventative remedy. Hydrothermal resources are of great importance for energy development.

Fresh groundwater resources in the country amount to 320 km3 per year (869.1 M m^3/day); only 2.3% of this value is used. The main part of resources (77.2%) is concentrated in four federal districts: Northwestern, Urals, Siberian, and Far Eastern, with the greatest amount in the Siberian (28.9%). Southern regions of the country with arid climates and northeastern regions with widespread permafrost are in shortage of fresh groundwater. On average, total consumption of groundwater per person in Russia (per capita consumption) is 170 l/day. The greatest amount of water is consumed in the Central Federal District (234 l/day), the smallest in the Northwestern Federal District (69 l/day).

Thermal water resources with a temperature of 50-100 °C and mineralization to 10 g/l amount in the territory of Russian to more than 2,000,000 m3/day. Pauzhetka (5 MW capacity) and Mutnovka (62 MW capacity) geothermal power plants are functioning on the Kamchatka Peninsula based on thermal groundwater.

These power plants provide 37% of the electricity needs in Kamchatka. Two small plants (2.5 MW) are operating on the Kuril Islands. Six more thermal water fields with a temperature above 90 °C and resources exceeding 770 kg/s are prepared for commissioning. Potential steam hydrothermal resources with temperatures of 150-250 °C in Kamchatka and the Kuril Islands can provide operation of a geothermal power plant with capacity of 800-1,000 MW. Thermal waters are widely used for heating of cities and towns and greenhouse farming (Stavropol Territory, Dagestan, West Siberia and other regions).

Mineral healing waters

Our country is rich in mineralized water resources – medicinal, thermal, and industrially valuable. Its territory has all the main types of healing waters known in the world. Russia currently operates about 430 deposits of underground mineral waters, on the basis of which 220 sanatoriums and therapeutic mud baths, and more than 100 plants for mineral water bottling are functioning. The number of fields varies from one in Chukotka to 250 mineral springs in the Irkutsk Region. The largest number of proven mineral water fields (78%) is in the central regions of Russia and the North Caucasus.

The first resort with ferruginous mineral waters in Russia was organized by decree of Peter I in Karelia ('Marcial Waters') in 1717. Mineral water is present both at the seaside resorts of the Kaliningrad Region and in the Far East. Nitrogen-siliceous thermal waters of Kamchatka being, according to the Japanese gerontologists, a powerful geroprotector, can compete with similar resorts in the land of the rising sun. Thermal waters are present even above the Arctic Circle, at the Talaya resort in the Magadan Region. The most famous resort region in Russia is the Caucasian Mineral Waters. A small area of the resort concentrates over 300 mineral springs of 24 different types. One of the resort towns in the region, Pyatigorsk, called a 'museum of mineral waters', has no equal in the world. Kislovodsk 'Narzan', waters from Essentuki springs No. 4 and No. 17, Pyatigorsk carbonated, carbonated-sulphurous, and radon waters, Zheleznovodsk thermal springs 'Slavyanovskaya' and 'Smirnoff' are especially famous and valuable.

Mineral water is used for the prevention and treatment of many diseases, such as gastro-intestinal, skin diseases, iron deficiency anemia and others.

Threats to water resources and their protection

The main problem arising in the exploitation of mineral therapeutic waters is associated with excess water intake over the value of natural resources, which leads to the depletion of aquifers, deterioration and thus reduction of the therapeutic efficacy of treatment. Thus, at the mineral water field 'Narzan', predatory water intake led to a significant reduction in the concentration of the main water component (dissolved carbonic acid) and caused changes in its ion-salt composition.

Careful attitude towards water reserves is the primary method of underground mineral water protection, and the preservation of its therapeutic properties and characteristics. When operating, one should take into account the recommendations of experts, which are mostly limited to requirements that intake not exceed the value of natural water supply.

Historical facts and legends

Oral histories about the miraculous properties of water from mineral springs passed down from one generation to another generation. Names of many springs speak for this. 'Narzan', or rather 'nart-sane' is an Abaza word translated as 'heroic source', or the source of heroic Narts tribe. The epics and legends composed about the spring say that its water returns health, beauty, and youth. Warriors going camping drank water from the spring, and it gave them unprecedented strength, endurance, and courage. There are the remains of ancient baths in places where natural mineral springs are sparkling out of the ground. These baths served not only for bathing, but also for mineral water treatment. Traveler Ibn Battuta, who visited the area of Pyatigorsk in 1377, wrote on the healing properties of 'Narzan'. According to travelers who visited those places at the beginning of the 18th century, there was a pole near the main spring with a silver bucket hanging on it as a symbol of deep respect for the miraculous source. They found several carved stone baths in the source area, at Goryachaya Mount in Pyatigorsk and near the source in Kislovodsk, which were designated for bathing. Local people successfully used 'Narzan' for treatment

Russia

of many diseases long before the arrival of the Slavic peoples.

Opening of resorts and the appearance of the first studies of sources is associated with Peter I. It was he who sent his personal physician Schober to the Caucasus and later issued a decree, which proclaimed therapeutic areas to be state-owned. In 1803, the state issued a decree in which the area of Caucasian Mineral Waters was called a therapeutic district of national significance. From that time begins the official history of Kislovodsk. Kislovodsk received its name from the source, whose water was called 'ache-su' by mountaineers, which means 'sour water'. A.S. Pushkin visited the Caucasian Mineral Waters: in 1820 and 1829 on the road to Erzurum. Lermontov wrote here one of his best works, 'Princess Mary'. This creation described the life and customs of the 'water community'. In 1863, the Russian Balneological Society was organized at the Caucasian Mineral Waters. This first Russian society of resort doctors was designed to unite achievements and develop the resort science. Many outstanding Russian and European scientists were members of the community. In the 1820s, Swedish chemist J. Berzelius and Russian professor and pharmacologist A.P. Nelyubin made the first chemical analyses of mineral waters and gave the first scientific grounds for their internal use. After investigation, A.P. Nelyubin created 'Full Historical, Medical and Topographical, Physicochemical, and Clinical Description of the Caucasian Mineral Waters'. But only in 1920, when the State Balneological Institute was established in Pyatigorsk, was a comprehensive study of natural mineral water effects started.

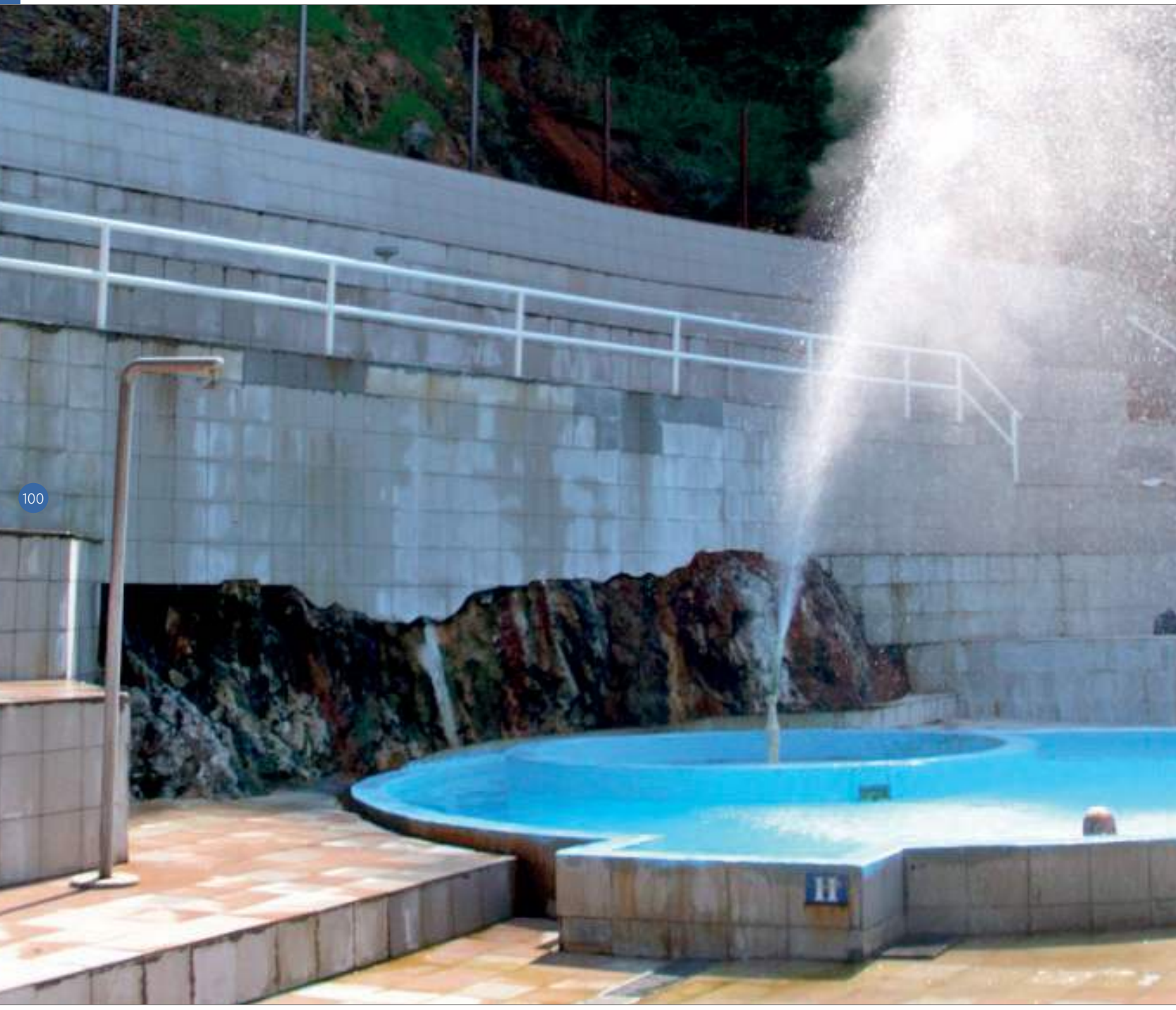
There is a story related to the first Russian mineral waters and mud resort 'Marcial Waters', located 50 km from the capital of the Republic of Karelia, city of Petrozavodsk. In winter 1714, a hammerman from Konchezero, I. Ryaboev, suffering from heart disease, was sent to Ravboloto to supervise iron ('swamp') ore carters. There he discovered a non-freezing spring, drank water from it and felt serious relief. Ryaboev told about the miraculous recovery to the Konchezero ironworks superintendent Zimmerman, who, in turn, informed the Olonets mining factories superintendent W. Hennin. Hennin, knowing the order of Tsar Peter I to find healing waters ('in the manner of Europe and France'), reported in writing to his superior, Admiral Apraksin.

Personal physician to Peter I, Dr. R. Erskine displayed a great interestin the 'Olonets waters'. In October 1717, he sent his assistant Laurentius Blumentrost (later the first President of the St. Petersburg Academy of Sciences) to study the spring, who made a chemical analysis of the water and, as Hennin wrote, 'exceedingly praised' it. Blumentrost drew attention to iron content in the studied water and therefore called it 'Marcial' (named after the god of war and iron Mars).

A.P. Karpinsky
all Russia Geological
Research Institute - VSEGEI

Vladimir Petrov, head of the Hydrogeological and Hydrogeochemical Division at A. P. Karpinsky Russian Geological Research Institute (VSEGEI); received his PhD degree in hydrogeology at the Mining Institute (Mining University) of Saint Petersburg, Russia. He specializes in regional hydrogeological, hydrogeochemical and paleohydrogeological studies.

Tatiana Ivanova, hydrogeologist-researcher in the Hydrogeological Division at A. P. Karpinsky Russian Geological Research Institute (VSEGEI); received her M.S. degree in hydrogeology at Saint Petersburg State University, Russia. Her research focuses on regional hydrogeology and mineral water resources.


II

Serbia

Introduction

The significance of mineral and thermal groundwaters in Serbia has been recognized from ancient times, testified today by numerous Greek and Roman baths or Turkish hammams. These waters have balneological value, and like that positive impact on health, body and soul. They are used for drinking, for recreation and relaxation, for treatment of many diseases, for cosmetic industry...

Lithology, tectonic assamblage of the terrain, the recharge area, age of water and hydro-geological conditions enabled forming of the groundwater rich with minerals, gasses and often with high temperature.

Numerous thermal and mineral springs exist in Serbia. The highest yield is from the springs and wells in the Mesozoic limestones, then groundwaters from granitoid and some metamorfic rocks, while the lowest yield that have springs from schist. In the view of temperature, situation is different, so the highest temperature have groundwaters from the granitoid and metamorphic Tertiary rocks, while the lowest temperature have karst groundwater, except groundwater in the Mačva area (northwest of Central Serbia).

Why are these waters special and good for our well-being

Special characteristics of groundwater are its temperature, mineralization and chemical composition. Mineral waters have high mineralization (TDS>1 g/L) and presence of some chemical elements (F, Br, J, Li, Mg, K...) or radioactive elements (Ra, Rn, U) in high concentration, or presence of gasses (CO_2, H_2S...). If mineral water has high temperature (usually higher than 20°C), it is named thermo-mineral water.

The use of groundwater for drinking and bathing can have influence on human health. Drinking water with high mineralization is good for sportsmen and people who are exposed to heavy physical work; high content of HCO_3 is good for gastritis; high content of Mg is good for cardiovascular system; optimal concentration of F is good for bones and teeth (from 0,7 to 1.5 mg/L); I is good for brain development in children, for hypothyroidism etc.

Chemical composition of water is important for balneological determination of water. Presence of some minerals in water defines water as good for some of the diseases. Bathing in thermal and mineral groundwaters shows good results in prevention and treatment of the skin, joints, reumatisms, cardio-vascular system, neurological diseases, gynecological diseases...

Enrichment with chemical elements is a consequence of deep circulation of the water, residence time, and interaction between water and the reservoir rocks. The most common gas in groundwater is CO_2, like result of numerous complex geochemical and magmatic processes at depth in the Earth's crust.

High temperature is consequence of intrusive bodies presence, which are, in some areas of Serbia, seen on the surface like granitoid massive or volcanic complex.

Use of the resource

In Serbia there are numerous traces of thermal and mineral waters usage in the ancient times, 2000 years ago, like Roman baths in the Niška Banja spa, Vrnjačka Banja spa, Lukovska Banja spa (Fig. 1) and others. There are also baths from the Byzantine times, and later hammams from the Turkish period.

At the end of 19th and begining of 20th century, Serbian state had invested and developed spa tourism, chemical analyses have been done, and population had used thermal and mineral groundwaters for the medical purposes and recreation. After WW2, geological and hydrogeological research of these locations were intense, and modern spa and health centers are developed, with pools, hotels, villa´s and in some case with bottling plants/factories.

Usage of thermal and mineral waters in Serbia is carried out mainly in the traditional way, for therapeutic purposes, bathing and swimming, while some mineral waters are bottled, and some thermal waters are used for heating, agricultural drying, greenhouses, industrial process, fish and other animal farming...

The following paragraphs will mention some mineral and thermal waters of Serbia. Waters are chosen with respect to the spatial distribution in Serbia, different chemical composition and different way of usage.

- The highest temperature of groundwater is measured in the Vranjska Banja spa (105°C), at the south of Serbia. Capacity of all wells is 100 L/s. Water is of the HCO3-Na, rich with B, Cs, F, Ge, Rb, W and SiO2. This water is used for balneotherapy, for heating some object, for greenhouses, chicken farm, and in past that water was used in industry.

- The most visited spa by tourists is the Vrnjačka Banja spa (central Serbia). There are several natural springs rich with the CO_2, HCO_3-Na chemical type. Groundwaters are bottled, and used in balneology and for recreation.

- Thermal water of the Ribarska Banja spa is low mineralized, with temperatures in the range from 26 °C to 54 °C. The mineral content of this water is low and its composition is of the SO_4-Na or HCO_3-Na type. Thermal groundwater is used in balneotherapy pools and for the pool of the Thermal Spa Center and for heating of the entire resort.

- Pribojska Banja spa is located in the south-west of Serbia. The main reservoir is limestone between the diabase-chert formation. Water is of the HCO_3-Ca-Mg, with temperature about 37°C. Water is used in balneotherapy and for drinking, being good for digestive system.

- In the Pannonian basin, groundwater from Novosadska spa is of the HCO_3-Cl-Na type, with high mineralization and content of I. Water is used for balneotherapy and for bottling.

Serbia

- Groundwaters in the spas of eastern Serbia, Niška Banja spa and Sokobanja spa, show radioactivity, having high content of Rn. Waters are low-mineralized, HCO_3-Ca-Mg type. These waters are used for the therapeutic and recreational purposes; while in these spas modern wellness centers exist.

On Serbian market, about 30 factories/bottling mineral water plants exist. There are oligomineral waters (EC<500 ×S/cm), mineral waters with elevated mineralization, then with presence of elevated concentration of some chemical element, and usually with presence of gasses (CO). There is no answer to the question "Which water is the best?", because all those waters are different and cannot be compared in that way.

Threats and protection

The highest threats for groundwater are humans and their activities. Unproffesional management of groundwater can cause overexploitation and reduce groundwater table. Other problem is pollution, usuall from industry, agricultural activities, lack of sewerage systems...

For prevention of polution and protection of groundwater, two regulatives exist in Serbia. Reserves of groundwater are defined according Regulative about classification and categorization reserves of groundwaters and keeping record of them («Sl. list SFRJ», br. 34/79), while protection of groudwater sources is regulated by Regulative about defining and maintaining sanitary protection zones groundwater source («Sl. glasnik RS», br. 92/2008. Sanitary protection zone of groundwater source is the area around the spring or well. In this area, construction of objects and other activities wich can affect groundwater source, and its chemical and physical characteristics, are closely monitored. Maps of groundwater vulnerability make important base to define sanitary protection zones.

Myths or stories

Some interesting stories and myths are related to thermal and mineral waters.

There is an interesting story about Sijarinska Banja spa and its geysers. In the middle of the 19th century, during drilling at the 9m depth, water fountain appeared up to the height of 8 m (Fig. 3). Temperature of water was 71 °C. About 50 meters away, another geyser appeared at a depth of 12 m. Geyser pulses at different intervals from 12 to 15 minutes with eruptions of water. Pulsation is caused by the onrush of CO_2 gas and water.

One of the youngest spas in Serbia is Vrdnik spa. At this location, the coal mine existed until 1968. During the mining activities, the Tertiary karst formation was penetrated resulting with the influx of 38°C thermal water, wich eventualy caused closing of the mine. Today, Vrdnik is very popular spa, and water is used in balneological puposes, and also for swiming pools, and the whole area artacts a lot of tourists.

A lot of springs in Serbia and all Balkans are dedicated to St. Petka (Paraskeva). Her relics have been located in Belgrade, but after the fall of Belgrade in 1521, Turkish sultan moved them to Constantinopolis, and after that to Lashi, Romania. There is a legend that on the way, at every of those places where people caring the relics stopped for overnight, a spring appeared.

One of the greatest myths in Serbia refers to mineral spring Devil's Water. Devil's Town (Fig. 4, located in south Serbia) is natural rarity having present earth pyramids (hoodoo) and two acid springs, Devil's Water (pH = 1.5, TDS = 15 g/L) and Red Spring (pH = 3.5, TDS= 9 g/L).

According to the legend, long time ago, this area was inhabited by humble, calm and religious people. This annoyed the devil so he made "Devil's Water" to make them to forget their lineage. As the inhabitants drank the water, they arranged a marriage between brother and sister. The devil's plan was interrupted by the fairy who, according to the legend, still keeps this area under her protection. The fairy could not reason with them, so the bride and the groom were on their way to the church. At that moment, the fairy started praying to stop somehow that incest. God heard her prayer, the cold wind blew and God turned the wedding guests into stone (earthen pyramides).

Geological Survey of Serbia

Tanja Petrović Pantić is adviser in the Geological Survey of Serbia, in the Department for Hydrogeology. She was awarded a PhD in hydrogeothermal resources at the University of Belgrade. Her research focus are thermal and mineral waters, hydrogeochemistry, geothermal energy, while she works on creating hydrogeological map 1:100.000 of the Republic of Serbia.

Slovakia

Introduction

Slovak territory is built by a wide variety of rock and sediment types. This is the result of geological and tectonic processes caused by the collision of the African and European lithosphere plates. Collision of these tectonic plates was accompanied by volcanic activity. Aquifers in Slovakia are mainly sediments from the Mesozoic, Paleogene, Neogene and Quaternary ages. Locations with the presence of mineral and thermal water springs in the territory between the Tatras and the Danube and Tisza rivers have been known for a long time by people living in nearby territories.

Slovakia is a country rich in water as it concerns amount, occurrence and chemical composition. While water in mountains and foothill areas comes to surface in the form of natural springs, in lowland areas, water sources are usually wells. The most abundant sources of water come from dolomites and limestones, or sands and gravels.

A special part of the groundwater is that which belongs to the mineral water and thermal water. Slovakia currently has more than 1,500 registered mineral water sources with different chemical compositions. Thermal water comes from springs or, more commonly, was tapped into by wells. There are over 140 registered wells with thermal water.

Picture © Spa Piestany

Why it is special and why it is good for our health

Water is the most common liquid. It is literally everywhere, even in our body. Indeed, water is absolutely necessary for all forms of life that evolved on Earth.

In the general sense, groundwater moves very slowly. The volume of water in the atmosphere changes every 9 days, but on average in groundwater only every 8,000 years, although there are considerable differences.

Groundwater in Slovakia is in special focus because of its use as the main source of drinking water. Main sources of groundwater come from recharge by atmospheric precipitation and surface water percolation through permeable layers.

Water emerging on the surface is enriched with dissolved minerals. Under suitable conditions, it is warmed by the Earth's heat and comes to the surface as thermal water.

Because of the variation in geological background in Slovakia, the chemical composition of mineral and thermal water is extremely varied. This diversity allows treatment of a wide range of diseases in thermal baths. Many of them are sold as bottled mineral water. Mineral water has positive effects on the human health, but regular drinking of some may cause clogging of the human health. So it is advisable to vary the types of mineral water used for drinking purposes.

Water resources distribution

Despite favourable hydrological conditions for the circulation and accumulation of groundwater resources, a major drawback is their uneven distribution.

The most significant amounts of groundwater resources for public drinking supply are located in western part of Slovakia (56%), which are bound to the Quaternary gravel and sand sediments of the Danube lowland. Significantly lower documented quantities of groundwater resources are in eastern Slovakia (17%). The remaining 27% is located in central part of the country.

Central Slovakia has the most springs with mineral waters. There are different types of mineral water, even when very close to each other.

Slovakia is very rich in sulphur springs that are most concentrated in the western part of the country. Composition of medicinal water of 'Smrdáky' spa (Slovak for 'stinky place') is quite unique and in use from the 19th century. One litre of the local water contains more than 3,100 mg of mineral components. The hydrogen sulphide content is especially high (more than 600 mg/l), which makes the Smrdáky water the most sulphurous water in Europe. Sulphurous mud is also highly curative. There are other sources of mineral water that have different amounts of dissolved minerals or special compositions of water. The highest dissolved mineral content is in curative water at Cígeľka, with more than 29 g/1.

Threats and protection

Groundwater, as the most important source of drinking water in Slovakia, is under increasing pressure from various anthropogenic activities, including global consequences from climate change, but also continuous growth in demand of good quality water in relation to demographic, social and economic development. All these factors threaten groundwater, and can have significant negative impact on the regime and quality of groundwater. Its protection is a priority task and a fundamental issue in all policies and visions for the development and sustainable use of water resources in Slovakia.

Another factor threatening the groundwater in Slovakia is excessive groundwater abstraction. An important task is the quantification of ecologically accessible amounts of water, e.g. the amount of water needed for aquatic ecosystems.

There are 75 groundwater bodies in Slovakia defined, all of which are used for water supply purposes and 26 geothermal groundwater bodies created beneath as separate layer. Threats to the quantity and quality of groundwater in the groundwater bodies of the Slovak Republic is a major concern.

Assessment of quantitative status is based on balance assessment of groundwater, assessment of long-term decreasing trend of the groundwater regime and the evaluation of flows in surface streams as they are influenced by groundwater abstraction.

In terms of threats to groundwater quality, a

Slovakia

good chemical status for groundwater body is that it meets quality standards outlined in Acts and other legislation.

Myths or stories

The existence of mineral and thermal waters in Slovakia represents natural wealth. Mineral water in addition provides assistance during therapy, refreshes the human body and helps to replenish minerals. Another dimension to this is the knowledge of how communities of people used the mineral and thermal springs throughout history.

Neanderthal man from Gánovce or petrified idea

Thermal water rich in mineral content and CO_2 with a temperature varying from 23 °C to 26 °C, springing in Gánovce village, created a travertine pile called 'Hrádok' (Slovak 'little castle'). The pile reached a diameter of 200 m and height of 20 m above the surrounding terrain. From the 1870s, mining of the travertine that gradually eliminated almost the entire travertine pile began. During extraction, numerous fossils were found (turtle carapace, snake skeleton, horse skull, etc.). In 1926, a tamper found a braincase casting in travertine sediment. He sold it to external collector Jaroslav Petrbok from Prague's National Museum. Petrbok identified it as belonging to a mammoth. In 1949, Emanuel Vlček discovered a brain cast of the skull of a Neanderthal. During a review of research in the years 1955-1960, on the eastern edge of the original spring depression, found among other things were the imprints of radius and fibula bones from a young Neanderthal. These were unrelated to the cranial cavity casting. M. Thurzo (1998) stated in its publication, that the cast is probably a female who died at a ripe old age. Travertine dating determined the absolute age of 105,000 years before present. The cranial cavity casting is deposited in the National Museum in Prague and a copy in the town of Poprad's local museum.

Healing water and mud in Piešťany

In the town of Piešťany, thermal water sources are found, with temperatures from 16.8 °C to 69 °C. The early settlement of the area, probably connected with thermal springs, dates back more than 24,500 years. The first evidence of inhabitation is the finding of the Moravian Venus statuette, cut from mammoth ivory at the campground site of mammoth hunters, about 1.5 km from the hot thermal springs. The boom in development at the spas started in the early 16th century, when spas were already famous in Hungary, Austria and other European countries. The first brick classical-style spa buildings were built in the period from 1820-1822.

Alexander Winter rented a rundown spa in 1888 and their descendants kept investing in the spas until 1940. In its early days of their investment, they built a spa hospital for ordinary workers if the cost of treatment was paid by the employer. Under the influence of this example, later social security in the Austro-Hungarian Empire included spa treatment in the framework of their care.

A significant achievement for the Winter family was in promoting the spa town of Piešťany abroad, where for this purpose they registered the trademark Spa Piešťany - Crutchbreaker. This symbol was to represent the healing power Piešťany thermal waters and mud. The slogan 'Rise up and walk' has been added to the symbol.

State Geological Institute
Of Dionyz Stur

Peter Malík has been head of Department of Hydrogeology and Geothermal Energy at the State Geological Institute of Dionýz Štúr (SGIDS) since 1994, working in the field of hydrogeology, and a staff member since 1984, coordinating and participating on more than 100 projects, and is author and co-author of more than 400 publications and reports.

Radovan Černák is a hydrogeologist at Department of Hydrogeology and Geothermal Energy, State Geological Institute of Dionýz Štúr, a staff member since 2002, coordinating and working on projects connected to hydrogeology and thermal water, and author and co-author of more than 60 publications and reports.

Daniel Marcin is a hydrogeologist at the Department of Hydrogeology and Geothermal Energy, SGIDS in Bratislava. He was awarded a PhD in Hydrogeology at Comenius University, Bratislava. He focuses on the evaluation of hydrogeological structures in terms of geological structure, geothermal balance, chemical and isotopic composition of minerals and thermal water. He is a member of the Commission for Mineral and Thermal waters IAH, the Slovak Association of Hydrogeologists, and the Slovak Geothermal Association.

Slovenia

Introduction

Groundwater is the main and nearly only drinking water resource in Slovenia, and karstic-fissured aquifers provide approximately half of it. Aside from direct consumption, groundwater significantly improves the comfort of our lives. Fresh groundwater can heat or cool apartments, irrigate garden plants or wash dusty cars. When water contains particular ingredients, such as dissolved ions, gas or heat, it becomes mineral and/or thermal water. These can help to improve our health, while steam can even be used in the production of electricity. The attractiveness of water features for tourism should also be acknowledged, as springs and karstic phenomena create natural heritage sites where people like to relax and recharge with good energy.

Many local names for places in Slovenia indicate that special groundwater was known to our ancestors. 'Toplica' (in English 'Spa'), and 'Perišče' (a place to wash) may indicate a subthermal spring with water temperature between 16 and 20 °C, or a thermal spring with at least 20 °C. Mineral water often contains more than 1 g/l of total dissolved solids, and is named 'slatina' or 'kisla voda' (in English 'sour water') if it contains lots of CO_2. According to our knowledge, there are over 10 subthermal springs, 50 thermal water sites, 15 mineral water sites and four mineral spring areas in Slovenia.

Finding unique water

Slovenia is a country of the classical karst ('Kras') and our world-known phenomena are related to fast and deep infiltration of cold rainwater. You can visit, for example, the UNESCO Škocjan Caves with an underground river, the intermittent Cerknica Lake, or catch the underground train in the Postojna Cave. Mineral or thermal springs emerge mostly along major faults or at contacts with less permeable rocks. Some were already in use during the Iron Age and by the Romans. Thermal springs in Bled, Čatež, Dobrna, Dolenjske Toplice, Laško, Rimske Toplice, Šmarješke Toplice and Topolšica are mentioned in documents from the Middle Ages; however, most health resorts were established only in the 18th and 19th Century. With increased needs for more and warmer water, the first geothermal well was drilled near a natural spring in Čatež in 1957. Nowadays, the deepest geothermal wells exceed 1000 m, in Cerkno, Rogaška Slatina and Zreče. Thermal water temperature is below 40 °C at most sites, but it reaches up to 64 °C in Čatež.

Porous aquifers are most extensive in the Pannonian Basin area in east Slovenia, and store important quantities of fresh drinking water. Temperature and mineralization of groundwater both increase with depth, forming mineral and thermal waters. The north-eastern part of Slovenia has many springs with mineral water and CO_2, but thermal water was not discovered until (unsuccessful) oil and gas exploration in the middle of the 20th Century. Few deep boreholes produce thermomineral water with lots of CO_2 and methane, but most wells yield moderately mineralized thermal water almost without free gas. The first geothermal well in this region was made in 1973 in Ptuj. Water temperature is between 28 and 75 °C, in general, of which the latter outflows from the deepest active well in Slovenia, the 1.8 km deep borehole in Benedikt.

Improving our well-being

The chemistry of water mostly depends on the minerals present in the aquifer and abundance of gases and organic substances. Rainwater that percolates in depths can become enriched in mineral substances that have positive and/or negative effects on our body. Groundwater from carbonate rocks is mainly rich in calcium, magnesium and bicarbonate ions, but sulphate and chloride may be locally important. In porous aquifers with old, Pleistocene rainwater, sodium and bicarbonate ions are the most abundant; however, brines of sodium-chloride type are also produced. High content of several ions, such as iodine or fluoride, or even radioactive substances, may help to cure various diseases.

Natural mineral water is used for bottling and drinking. You have probably heard about two of our worldwide known brands of high mineralized water: Radenska Classic Petanjski vrelec from Radenci, and Donat Mg from Rogaška Slatina. Radenska was first bottled in the 19th Century, and soon became so famous that it was drunk by the Habsburg royal family and the Pope. Drinking it helps mitigate kidney and urinary tract diseases. The second, Donat Mg, was declared a curative water and already bottled in the 17th Century. It had a great reputation as a medicine at the Vienna Court and it became the third most-sold water in the world in the 19th Century, right after Vichy and Selters. Selling this water was such a good business that even counterfeits were distributed, and usage disputes on bottling rights occur even now. You will never forget drinking too much Donat Mg because it will not give you a hangover, but rather a diarrhoea caused by very high magnesium and sulphate concentrations. When taken as a cure, this water can support digestion and hasten regeneration after sports.

Most of our thermal waters treat rheumatic conditions and help with recuperation of the musculoskeletal system, and several have specific indications. Here, we give you two such examples: high organic compounds in the 'black thermal water' in Moravske Toplice, or 'paraffin thermal water' in Lendava may help to cure your skin, while bathing in CO_2 rich thermomineral water in Radenci can improve your heart condition (but be aware that love problems are not included in the medical treatment).

Use of mineral and thermal water

Today, nine Slovenian waters are declared natural mineral waters for bottling, and most of them are low to moderately mineralized. In 2014, thermal water was produced at 32 sites, providing also as much as 15.5 ktoe of geothermal heat. Almost half of that was used for individual space heating at 18 locations, mostly spas. One quarter was used for heating of four greenhouses, and a little less was used

Slovenia

for bathing and balneology in 26 spa and wellness centres. A very low percentage is attributed to three district heating systems, to air cooling, and to sanitary water heating systems.

There are many natural health resorts that use medicinal thermal water, and development of several villages was strongly connected with its discovery. A settlement of Moravci was an ordinary Pannonian village until oil investigators made a few unsuccessful deep boreholes in the middle of the 20th Century. They abandoned the site, but the local inhabitants opened the valves and soaked in hot and smelly black water, spreading rumours on its curative effects. They were also very lucky that their smoking at the wellhead with high methane emissions (recalling the past, when almost everyone smoked) did not cause a severe ignition. The village changed its name from Moravci to Moravske Toplice in 1984, adding the expression 'spa'. No one knows if they plan to change it back if they run out of water in the future.

Another story is connected to renaming of a health resort in Podčetrtek. Its development started when the Atomske Toplice (in English 'Atomic/Radioactive Spa') was opened in 1966. At first, the advertisements highlighted occurrence of this mildly radioactive thermal water as having important curative effects. Unluckily, after the major accident in Chernobyl in 1986, even natural radioactivity gained very negative connotation. Therefore, the spa was renamed to Terme Olimia in 2003, after the nearby Olimje Monastery from the Middle Ages.

Threats and protection

Quantity and quality of these waters is severely threatened by current practices of exploitation. Several mineral water springs in Ščavnica valley dried out due to land reclamation along rivers, which decreased groundwater levels. Many thermal springs ceased to discharge after geothermal wells started producing, as did the one in Rimske Toplice, which occurred approximately 40 m above the valley floor due to unique geological settings. Aquifer depletion has also resulted in groundwater level drawdown and inflow of less mineralized and/or colder water.

There are strong efforts to implement more sustainable exploitation practices. The most important issues are to raise public awareness on the vulnerability of water resources, to prevent over-exploitation, to change behavior of well managers in order to increase thermal efficiency of geothermal energy abstraction, and to implement reinjection at sites where only heat is being used. Applying this, our children will be able to enjoy themselves on water slides while we seek health bathing in hot and smelly water for many years to come.

Geological Survey of Slovenia

Nina Rman is a Research Assistant at the Groundwater – Hydrogeology Department of the Geological Survey of Slovenia and an Assistant in Geology at the Faculty of Natural Sciences and Engineering at the University of Ljubljana. She holds a PhD in Geology from the latter institution and she specialized in geothermal energy technology at the University of Auckland. Her activities include investigation of mineral and thermal water and promotion of geology. She is a secretary of the Slovenian Geological Society.

Andrej Lapanje is a Senior Expert at the Groundwater – Hydrogeology Department of the Geological Survey of Slovenia. He holds an MSc in Geology from the University of Ljubljana. His research is linked to all aspects of hydrogeology, with the strongest focus on exploration of thermal water and utilization of geothermal energy. He is also a national expert in Geothermal Energy for the EFG panel.

Spain

Introduction

Mineral and thermal waters are natural resources of extraordinary value and part of the historical and cultural heritage of Spain. Their use over the centuries is reflected in the abundant archaeological vestiges scattered throughout the geography and in documents of varied natures written during and since historical times. Treaties, handbooks and yearbooks show the existence of these waters and provide a variety of information: from their location and physicochemical characteristics to the presence of historical figures in watering places.

Water's healing power and special qualities were already evident in El Ingenioso Hidalgo Don Quijote written by Miguel de Cervantes:

"... And then he would drink a great jug of cold water and become calm and quiet, saying that this water was a most precious potion which the sage Esquife, a great magician and friend of his..." (Chapter V).

In Spain, a bath resort is a recreational and therapeutic centre, with medical services and appropriate facilities, whose waters have been officially declared mineral-medicinal and/or thermal. There are other establishments, such as spas and thalassotherapy centres, which use water as the main element in their activity, but whose waters have not been declared mineral-medicinal or thermal.

There are now 106 operating bath resorts in Spain, spread throughout its geography. They generate a direct employment of 3,000 and many others in related facilities. Among them, 24% are located in areas of high ecological value, giving them an added value.

Why it is special and why it is good for our well-being?

The difference is in the water.

One main feature of mineral and thermal waters, which makes them different from other waters of the hydrological cycle, is the long residence time in the aquifer, where they are subjected to physical and chemical interaction processes with the bedrock, under conditions different from those of surface waters.

These waters can reach high temperatures and/or exchange materials with the bedrock, dissolving or precipitating substances, incorporating salts and/or gases to its composition. Those physicochemical features determine their 'hallmark'.

Spain has a great variety of mineral waters, which is a reflection of its different geological domains.

Calcium bicarbonate waters are the most representative, and are associated with marine or continental carbonate materials. They are found in several Spanish ranges, including the Cantabrian, Pyrenean, Iberian, Catalan Coastal and Mallorca; and in the tertiary depressions of the Duero, Tajo and Guadiana rivers. In these same areas, we can find magnesium bicarbonate waters, but only in places with a predominance of dolomite limestone and in volcanic areas such as Ciudad Real and the Canary Islands.

A second important group is formed by sodium bicarbonate waters, associated with igneous and metamorphic materials. They are located in the western of the Iberian Peninsula and in the Canary Islands.

In coastal areas, formed by evaporitic Triassic materials, chlorinated sodium waters are common. They are found in Galicia, Asturias, Guadalquivir depression and the Iberian Range.

Finally, associated with Triassic gypsum and anhydrite, sulfated calcium waters prevail.

Medical hydrology determines the properties and therapeutic uses of these waters, according to their chemical composition, temperature, radioactivity and microbiological quality. Therefore, bicarbonate waters are used for digestive problems, sulphate waters are good for the skin, the respiratory system and the musculoskeletal system, and ferruginous waters favour the regeneration of blood.

All the different health, relaxation and/or beauty programs offered by bath resorts are intended to be preventative and improve vital functions, such as rebalancing the mind and body, improving the image, and providing greater energy balance and a deep wellness.

Threats and protection

The underground location of mineral and thermal waters provides them a natural protection, which is complemented in Spain by the legal requirement of protection perimeters. This is defined by hydrogeological criteria and it limits land use, depending on its proximity to water intake, thus preventing both pollution and overexploitation. These waters are usually located in environmentally protected areas, which improves their preservation.

A potential threat to the use of this resource is the existence in the area of similar centres like Spas, thalassotherapy centres, etc. In Spain, this threat is increasing due to the dependency of baths to health programs like IMSERSO, for elderly people, subsidized by the administration.

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Myths or stories

The attribution of therapeutic benefits to certain waters that surged form the underground comes from prehistoric times. A good example of this are the megalithic monuments, dolmens and petroglyphs near the bath resort of the village of 'Alicún de las Torres' (Granada). They are dated between the Neolithic and the Bronze Age periods, when a divine or supernatural origin was attributed to those waters. They are evidence of the relationship between prehistoric men and mineral waters.

The Roman domination of Spain was the golden age of bath resorts. Many facilities were built then, many of which are still active: Alange, Caldas de Malavella, Ledesma, Montemayor, Puenteviesgo, etc. The baths of Alange (Badajoz) benefit from the healing power of its waters, famous because they healed a young roman patrician. This then favoured the construction of the resort, founded by his father. In 1993, the whole

Spain

thermal complex was declared World Heritage by UNESCO. Another good example are the thermal springs of 'Las Burgas de Ourense' (Galicia), an architectural complex formed by three public fountains whose waters, surging above 60 °C, were considered sacred and associated with the pre-Roman aquatic deity 'Revve Anabaraego'. Subsequently, during the Christian era, they were related to hell because of their high temperature.

At the beginning of the Middle Ages, the use of these waters decreases in the Christian territories, although it remained in some religious-military orders such as the Knights of Santiago and San Juan, who used them to heal their wounds. In the territories of the Arab domination in the south of Spain, new baths such as Alhama de Granada, Alhama de Murcia and Graena were built.

In the Early Modern Period, the use of these waters rose again, as well as interest in their study from a scientific point of view. Due to its antiquity and importance, we should highlight the treatise Espejo Cristalino de las aguas de España (Crystal mirror of the waters of Spain), written in 1697 by Alfonso Limon Montero. During the mid-eighteenth century, the mineral waters used in the baths of Cestona (Guipúzcoa) were discovered due to the healing of Marquis of San Millán's dogs. The water that comes from the spring 'San Ignacio' is used for liver and biliary diseases, and the spring 'Nuestra Señora de la Natividad' is used for kidney diseases. On the island of La Palma (Canary Islands), it is worth citing 'Fuente Santa', discovered by the first settlers. The conquest of the island by the Crown of Castile allowed his fame to spread, so in the seventeenth century it was visited by sick people from different places in Europe and America. Its waters were exported to the New World in barrels for relief of diseases such as leprosy, gout and syphilis. In 1677, an eruption of the San Antonio volcano buried it under thick rivers of lava. For over three hundred years, there was an unsuccessful search for the spring, which finished at the beginning of the XXI century, when it was located by digging a gallery.

During the Late Modern Period, the popularity of bath resorts increased. Some of them were refurbished and new ones were built. The baths of Mondariz (Pontevedra), built for the privileged classes of that time, is considered one of the most important hydrotherapy centres in Spain. It used to be visited by the Spanish royal family during different reigns. In this period, different uses of mineral and thermal waters arose. In some baths, like Paracuellos de Jiloca, cosmetic programs have been developed using thermal waters rich in minerals, which are intended to take care of the skin.

This historical journey has tried to show a glimpse of the relationship between mineral-medicinal waters and health, since the beginning of civilization until today. This relationship is quite prominent in the life of the inhabitants of the 'Villa Termal de Lanjarón' (Granada), whose citizens are among the ones with longer life expectancy on earth. They say their water is the 'water of life, health and eternal youth', similar to those sought by the Spanish explorer and conqueror Ponce de León in Florida, back in 1513.

As Hippocrates would say: "A doctor cures; only nature heals'.

Geological Survey of Spain

Elena Galindo Rodríguez. Hydrogeologist. Master's degree in Hydrogeological Technology at the Polytechnic University of Madrid and International Master's degree on General and Applied Hydrology at the Center of Studies and Experimentation on Public works (CEDEX). She has worked in the fields of hydrogeology in the Geologic Survey of Spain (IGME) for more than 20 years, currently in the Mineral and Thermal Waters Service.

Carlos Ontiveros. Degree in environmental sciences. He has been working since 2006 in the Hydrogeology Department in the Geological Survey of Spain (IGME). He is currently in the service of the Mineral and Thermal Waters Service.

José Ángel Díaz Muñoz. Hydrogeologist. International Course on Groundwater Hydrology, Polytechnic University of Catalonia and International Master´s degree of General and Applied Hydrology, Centre of Studies and Experimentation of Public Works (CEDEX). He has been employed at the Hydrogeology Department in the Geological Survey of Spain (IGME) over more than 20 years; he is currently in the Mineral and Thermal Waters Service.

Sweden

Introduction

Groundwater forms a significant part of the hydrological cycle, but it is often forgotten. Despite the importance of groundwater to society, its contribution is seldom recognised. An estimate made by the Swedish Geological Survey shows that the groundwater aquifers in Swedish sand and gravel deposits are capable of providing some seventy-five million people with drinking water. A further 10 to 30 million people could be supplied by groundwater aquifers in sedimentary and, potentially, in crystalline bedrock. These numbers, though approximate, show the importance of groundwater as a current and potential future water resource for the people in Sweden.

Pre-historic settlements in Sweden were generally located close to eskers and springs because of the ready access to fresh water. Later on, in historic times, natural springs provided a source of clean drinking water - in stark contrast to the murky surface waters polluted by humankind. Groundwater, especially from springs, was probably an important factor for human well-being and even survival. During the last three centuries, hundreds of watering places and around a dozen larger health resorts in Sweden have been visited for health and relaxation purposes. Groundwater is important for more than just drinking – many of the benefits we receive from nature and from cultural and outdoor life can be attributed to our groundwater resources.

Why it is special and why it is good for our well-being?

The main aquifers in Sweden are situated in sand and gravel deposits, mainly eskers. These deposits cover only some 4% of the land surface, but their annual water recharge amounts to 7.3 billion m^3. The eskers originate from the last glaciation and consist of assorted sand and gravel deposits. Most were formed within ice tunnels, where submerged streams flowed, transporting material inside the continental ice sheet which covered northern Europe from 70,000 to 10,000 years ago. The aquifers in these eskers are by far the most important groundwater resources in Sweden. The sandy gravelly material and great thickness of the eskers act as a filter for natural purification and provide large storage volumes. Regionally – mainly in the south of Sweden – aquifers of importance can also be found in sedimentary rocks.

A large proportion of the most significant Swedish springs are located at the base of eskers. Well into industrial times it was common for Swedish towns to be supplied with drinking water from a well located a few hundred meters from the town centre, the water being supplied through pipes by gravity. Their pristine nature makes springs excellent environmental indicators, and a number of springs have been monitored in Sweden since the 1970s. In Sweden, all springs are cold springs. The average temperature of 4-8 °C is generally kept all year, depending on where in Sweden the spring is located. During the last century hundreds of spring-based watering places and a dozen larger health resorts were established in Sweden. People who believed in the beneficial nature of spring water visited these sites to relax away from their everyday life, a kind of health injection. Carl von Linné, whose ability and thirst for describing and classifying all things, observed and registered facts about springs during his travels across Sweden. At that time, the spring resorts constituted an important ingredient in human lives. Wealthy and poor alike were welcome to the health springs and people paid according to ability. Swedish springs and their special local environment have been illustrated and acclaimed in Swedish art, literature and music. As an example, one of the most beloved Swedish summer songs, sung by all school children at the official start of the summer holidays, was composed in the shade of a willow tree adjacent to a spring on the island of Gotland.

Groundwater is also important to ecosystems, especially for so-called groundwater-dependent ecosystems, e.g. wetlands and spring environments, where a continuous supply of clean groundwater is vital for the ecosystems to survive and flourish. These fragile and exceptional environments depend on both the quantity and quality of the groundwater.

Use of the resource

Many of the pre-historic settlements in Sweden, as early on as the Neolithic times, were located close to springs. Apart from being important as a drinking water resource, the springs provided important watersheds for meadows, as well as providing seepage water essential to animal husbandry. Today, fifty percent of the Swedish population drink groundwater from the tap every day. Half of this groundwater constitutes natural groundwater and the other half consists of surface water which has been allowed to infiltrate through sand and gravel deposits to create more groundwater. Additionally, more than 1 million people are provided with drinking water from some 500,000 private wells, usually drilled into crystalline bedrock. Some of these wells have problems originating from natural causes, e.g. due to the nature of the bedrock. Elevated levels of radon and uranium are examples of such problems.

Groundwater from springs is used to provide drinking water, both as mineral water in bottles and as water sources for small municipality water works. In the 17th century, the chemist Urban Hjärne was appointed to find and explore springs in Sweden, and in the late 17th and early 18th century commercial wells were established at spring locations like Medevi and Ramlösa. Ramlösa still produces mineral water sold in bottles, but today the water is taken from drilled wells. The Medevi well is still a spa resort, where you can drink a glass of health-beneficial spring water in a relaxing environment. Cities like Uppsala and Gothenburg used springs as their drinking water supply for several centuries. But today the city of Uppsala (with 200,000 citizens) utilises the groundwater from the large esker Uppsalaåsen, another irreplaceable groundwater resource.

Groundwater is also used for the heating and cooling of buildings. There are roughly 150 large-scale Aquifer Thermal Energy Systems (ATES) in Sweden, providing some 800 GWh - of these, 350 GWh are utilised for cooling purposes. Swedish thermal wells can be found

Sweden

both in eskers and in sedimentary and crystalline bedrock.

Threats and protection

The great eskers in Sweden are endangered by quarrying for sand and gravel. The creation of Water Protection Areas is an important protection tool against further quarrying. Since the early days of humankind, sand and gravel eskers have been used as suitable sites for the construction of villages, roads, cities and railways. For this reason many eskers are subject to pollutant pressure from a number of human activities. The lack of three-dimensional planning in urban areas constitutes a great challenge for the sustainable use and protection of groundwater. Insufficient information is another problem. More data and information on groundwater levels and chemistry are required, including data collected over a number of years so that trends can be followed and analysed.

Many springs are negatively influenced by agricultural practices like drainage ditches and the use of fertilizers and pesticides. An important way of gaining support for the protection of springs is to make them known to the general public. The Swedish Spring Academy was established in 1978. The aim of the Academy is to promote interest in springs and to contribute to their preservation, nurture and usage.

Myths or stories

In Sweden there is a long tradition of using springs for cult purposes. In the former town of Old Uppsala, several springs were used as sites for sacrificing humans and animals for over 1,000 years. Some churches and cathedrals still harbour a spring well in the crypt, and many springs have been used for baptismal purposes.

In the old Norse mythology, the tree Yggdrasil is at the centre of the Scandinavian cosmos. Spreading its branches across the world, it is supported by three long-reaching roots which extend into Asgård (home of the gods), to Jotunheim or Utgård (home of the giants) and to Nifelheim (the underground). The three roots receive water from three wellsprings: Urdarbrunnr, where the trio of norns decides the fates of people; Mimisbrunr, where the god Odin once placed one of his eyes in exchange for a drink (and eternal knowledge) from its water, and Hvergelmir, a bubbling spring and the source of many rivers. The Hvergelmir spring is also home to the dragon Nidhögr which gnaws on the root of Yggdrasil.

Geological Survey of Sweden

SGU

Dr. Peter Dahlqvist is a hydrogeologist and sedimentologist at the Geological Survey of Sweden. His work involves a wide range of groundwater issues: groundwater mapping and valuation, environmental objectives, shallow geothermal energy, etc. Peter is a member of the SUB-URBAN work group, COST-action TU 1206, a network set up to improve the understanding and usage of the ground beneath our cities.

Switzerland

Introduction

The geology of Switzerland is very diverse. There are essentially three main areas, which are also very different in hydrogeological terms. These are: the Alps, a complex geological structure with strongly tectonised nappes and extensive crystalline massifs in the south-east; the Tertiary Molasse Basin on the Central Plateau, with its relatively simple structure; and the Jura Mountains in the north-west, which are folded and tectonically dismembered, especially in the southern part. The Alps and the Jura Mountains are rich in mineral and thermal springs, as both their tectonic fragmentation and pronounced relief structure allow groundwater to rise hydraulically from great depths to the surface. In contrast, the densely populated Molasse Basin has very few naturally occurring mineral and thermal springs.

In the Jura Mountains, sulphate-rich calcium-magnesium-hydrogen carbonate waters dominate. These are frequently also rich in sulphides (H_2S gas, hydrogen sulphide and sulphur). They document the dissolution of sulphate rocks (anhydrite, gypsum) and carbonates originating in the sediments of the middle and late Triassic. To some extent, they also document the dissolution of rock salt from the same sediments.

The chemical composition of the water rising from deep below the Alps is more diverse. Besides dissolved evaporates and carbonate rocks, this deep groundwater contains a high concentration of components which are dissolved as the water flows through crystalline rocks. There is a special situation in the canton of Graubünden, where many of the local mineral springs (eg. Scuol-Tarasp, St. Moritz

and Passugg) contain large quantities of carbonic acid and free CO_2 gas. This gas must rise from great depths along fault zones and become enriched in permeable rocks.

Why it is special and why it is good for our well-being

Switzerland has 20 large thermal spas. These are not merely valuable tourist attractions, but also centres of regional development for business, culture, entertainment and sports. Settlements often grew up around thermal baths, followed by further socio-cultural development and differentiation. There are two main types of spa:

- Thermal baths near major towns and cities, which provide not only health treatments and health prevention services, but also pleasure and relaxation for the urban population. Examples include Baden-Ennetbaden, Yverdon and Schinznach and the saltwater baths at Rheinfelden and Locarno, where the water is tapped artificially. In the last 20 to 25 years, hundreds of millions of Swiss francs have been invested in renovating and expanding these baths. Several hundred million francs in additional investment are planned in coming years.

- Thermal baths in the inner-Alpine area. Although more difficult to access from urban centres, the advantages offered by these spas include magnificent surroundings, a quiet atmosphere and clean air. They are important tourist destinations, complemented by attractions such as hiking, winter sports, tennis, golf, concerts, etc. The Alpine spas are important for tourism because they attract an evenly distributed flow of visitors throughout the year in otherwise typical winter sports destinations. These spa resorts have therefore developed into regional centres and continue to expand in many sectors, including hospitality, construction, culture and sport.

The tapping and bottling of mineral water as a beverage is an important economic sector in Switzerland, as mineral water consumption has been increasing for decades. Currently, more than 500 million liters of mineral water are bottled and sold every year. The health aspect is also a sales argument, although Swiss tap water, which is 80% groundwater, is of excellent quality everywhere.

Water resources for health and well-being

The largest of the more than 20 thermal and mineral water springs in Switzerland are:

- Lavey-les-Bains (Alps, photo pages 120-121): found here are the warmest springs in Switzerland (68 °C). Believed to have been used by the Romans, in 1831 they were rediscovered by some fishermen, who found a warm river current in the Rhone. Former spring captures at the riverbank were replaced by two bore holes. Two hydrogeological investigations suggest that the reservoir temperature is between 100 °C and 110 °C and its depth is around 3500 m. Water type: Na - SO_4 - Cl, rich in Li and F.

- Leukerbad (Alps): Baths since medieval times, with many large hotels springing up from 1840 onwards. Approximately 60 springs (42-51 °C; 1600 - 2500 l/min). Water type: Ca - (Mg) - SO_4 - (HCO_3).

- Brigerbad (Alps): Used as a thermal bath in Roman times and in the Middle Ages. In the 15th century a rockslide subsumed it, but it was cleared in the 16th century and the spa rebuilt. Springs with 21-50 °C; 3000 l/min. Water type: Na - Ca - Cl - SO_4, rich in Li.

- Yverdon-les-Bains (Molasse basin, southern foot of the Jura mountains): Springs used for bathing and drinking. Source of the water is a 29 °C sulphurous spring. The water has been used since Gallo-Roman times. At that time the town was called Eburodunum. The town has been famous for its spa treatments since the 17th century. Water type: Ca - (Mg) - SO_4 - (HCO_3) rich in Sr; thermal and mineral waters have different mineral compositions.

- Bad Schinznach (Jura mountains): Balneological use since the mid-17th century. Artesian thermal spring with partial addition of cold water. Water now tapped by boring directly into the Muschelkalk formation (44 °C). Water type: Na - Ca - Cl - SO_4, with a high concentration of hydrogen sulphide (51 mg sulphide/l).

- Baden - Ennetbaden (Jura mountains): Roman spa town (Aquae Helveticae), destroyed around AD 260. Little use in medieval times; baths intensively frequented from the 16th century onwards. Water type: Na - Ca - Cl - SO_4, with a high concentration of Li, Sr, F and H_2S. Nineteen known springs (47 °C; 600 - 800 l/min).

Switzerland

- Bad Pfäfers - Bad Ragaz (Alps): The spring (37 °C; 5000 - 7000 l/min) is situated in a narrow gorge near Pfäfers. As early as 1038, patients were lowered to the spring on ropes and baskets. The first bathhouse was built in Bad Pfäfers in 1242. In 1840 the thermal water was routed four kilometers along wooden channels through the Tamina gorge to Bad Ragaz, where in 1872 Europe's first indoor thermal pool was created. Water type: Ca - Mg - Na - HCO_3 with a high concentration of F. It is Europe's highest-flow acratotherm spring (total mineralisation is only 412 mg/l). The water rises on an almost vertical fault crossing the gorge.

- Scuol-Tarasp-Vulpera (Alps): The numerous mineral springs were already in use by Roman times and in the Middle Ages. Spa tourism developed in the 19th century when the Engadine valley was made accessible by road. Water types: Ca - HCO_3, partially with high concentrations of Na and Mg, turning to Na - Mg - HCO_3 - SO_4 waters. Individual springs have significantly different mineral contents (2 g to 17 g/l), often with large amounts of Li, Sr, Fe, boric and silica acid. All springs are cold (6 °C – 12 °C) and the water temperature is raised to bathing temperature using geothermal energy. All springs contain high amounts of CO_2 (2 g to 7.8 g/l) which also escapes into the atmosphere via mofette (dry CO_2 escapes to the surface). It has been calculated that several thousands of m^3 CO_2 escape daily from the depths of the earth in this area. Such a high amount of CO_2 indicates that thermo-metamorphic processes occur at a depth of several kilometers.

Other major thermal and mineral water springs in Switzerland are:

- Lostorf and Eptingen (mineral waters with a very beneficial composition), Bad Zurzach (alkaline Glauber's salt spring), Henniez (weakly mineralised mineral water, routed by the Romans to baths at the regional capital Aventicum, now known as Avenches), Vals (bathing and mineral water), Passugg (cold mineral water spring with large amounts of CO_2), St. Moritz (cold spa spring with large amounts of CO_2), Val d'Illiez (bathing and mineral water), Aproz (mineral water) and the thermal baths Ovronnaz, Saillon, Bad Ramsach and Acquarossa.

Myths or stories

The first physician to study the Swiss mineral springs closely was Paracelsus (Theophrastus Bombastus von Hohenheim, 1493 - 1541). He was born in the former Swiss Confederation and worked for some time in Basel. He also studied balneology and the possible healing processes affected by spa treatments in some detail. In 1535, he worked for several months in Bad Pfäfers, wrote a paper about the healing effects of the thermal spring there, and recommended the thermal baths at Scuol-Tarasp and St. Moritz.

The Schwefelberg-Bad spring is located on an Alp (meadow) at an altitude of about 1500 m around 30 km south of Bern. In the 17th century, the Bernese government banned bathing due to moral laxity and debauchery at the remote location. It was not until the 19th century that spa treatment was again permitted in supervised bathhouses.

Geological Survey of Switzerland

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Hans Burger, PhD, geologist, member of the Federal Geological Commission (EGK/CFG), a permanent extra-parliamentary commission which advises the Swiss Federal Council on applied geology. He worked 28 years for a law enforcement authority and some years in engineering and geological offices, and is a specialist in hydrogeology and environmental geology.

Ronald Kozel, PhD, hydrogeologist, is the head of the Hydrogeological Basics Section at the Swiss Federal Office for the Environment (FOEN). He represents Switzerland in the EuroGeoSurveys Water Resources Expert Group (WREG) and is a member of the International Association of Hydrogeologists (IAH). From 2004 to 2010, he was the president of the Swiss Hydrogeological Society.

Turkey

Introduction

Groundwater is a major source of drinking water across the world and plays a vital role in maintaining the ecological value of many areas. However, the quantity and quality of groundwater is changing as a consequence of human activity and climate variability. The demand for water is rising as population, economic activity and agricultural irrigation grow. However, worldwide resources of accessible water are decreasing due to overuse or pollution.

Turkey is considered rich in groundwater. Landforms and geological structure determine the characteristics of groundwater. Plains and deltas, especially in the coastal regions of our country, have fairly rich groundwater. Groundwater in Turkey is used for a variety of purposes. It is as a primary source of irrigation water in basins, where sufficient surface water resources are not available. Groundwater is also used as a supplement to surface water resources for irrigation and domestic water supply. More recently, groundwater has been used for industrial processes, and as a source of geothermal energy.

Why it is special and why it is good for our well-being ?

Meeting the water needs of growing population and industry with surface water is not always possible. Therefore, groundwater is of particular importance. The main source of groundwater is constituted by rainfall. A portion of the rainfall evaporates, some seeps down to a layer of the earth, and a portion of that infiltrates through to become groundwater. Groundwater located in underground layers is called an aquifer. Groundwater has different minerals of different proportions that are vital for people.

Groundwater wells at the surface meet a part of people's drinking water needs. Today, approximately 14 billion m^3 of groundwater is estimated to be found in Turkey. Most residential units' and agricultural activities' needs are satisfied in this way. Examples of large areas of groundwater use in agricultural activities can be found in the plains of Konya Karapinar, Eskisehir Alpu and Afşin-Elbistan, for instance.

Hot and mineral water, is used for both drinking and its healing aspects. Turkey has quite a long history of this, and these spa resources are used throughout historical periods. Examples of the most important spas, such as Bursa-Kaynarca, are available on request . Known to be in use since 1365, the temperature of the Çekirge thermal spa's water is 45 °C, while that at the Kaynarca thermal spa is 90 °C. However, these may be rerouted to significant greenhouse operations in Turkey.

At high temperatures (80 C), groundwater is suitable for geothermal fluid power generation. There are suitable areas in Turkey for the production of electricity from geothermal fluids. Examples include (among others on request) the Denizli-Saraykoy, Aydin-Germencik, and Çanakkale-Tuzla areas.

Myths or stories

In Turkey, geothermal energy is mainly used in thermal tourism, heating applications, greenhouse heating, industrial mineral and in electricity production. MTA discovered 229 geothermal fields, of which 25 geothermal fields are suitable for geothermal power production.

The electricity production fields and their installed capacities are ; Denizli-Kızıldere (95 MWe and 6.85 MWe), Aydın-Germencik (47.4 MWe and 45 MWe), Çanakkale-Tuzla (7.5 MWe), Aydın-Salavatlı (7.95 MWe, 9.5 MW, 34 MWe), Aydın-Bozköy-Çamur (92 MW), Aydın-Pamukören (45.02 MWe), Aydın-Gümüşköy (13.2 MWe), Manisa – Alaşehir (24 MWe). Total constructed electricity capacity is 427.4 MWe. Taking into account all the additional development studies concerning all discovered geothermal fields, electricity production from geothermal energy could reach 1,000 MW.

In Turkey, direct use applications from geothermal energy include district and greenhouse heating and thermal tourism facilities. Currently, there are 18 settlements which use geothermal for central home heating (89,563 residence equivalence, 806 MWt), 21 fields where greenhouse heating is applied (3,130 decare, 543 MWt) and more than 350 thermal resorts that offer balneologic treatment and thermal tourism applications.

Turkey

General Directorate of Mineral Research and Exploration

Barbaros Erduran is hydrogeology engineer at Department of Energy Raw Material Research and Exploration in MTA. He graduated from the Hydrogeology Engineering Department of Hacettepe University.

Zeynep Gürel Aktaş is hydrogeology engineer at Department of Energy Raw Material Research and Exploration in MTA. She graduated from the Hydrogeology Engineering Department of Hacettepe University.

ЛЕД-ПАЛАС

Ukraine

Introduction

Groundwaters are among the most important minerals of national importance. They have a dual nature. On the one hand, this is a moving commodity that circulates in the rocks and its use requires extraction from subsurface, and on the other hand it is a part of the total water resources of the planet, which interacts with surface waters, atmosphere and other components of the environment. In this regard, groundwater resources depend not only on geological and hydrogeological but also on the physical and geographical factors as well as man-made ones that change groundwater supply conditions, their quality and the possibility of production and use.

Ukraine is extremely rich in various mineral waters. Transcarpathia can be considered as the pearl of Ukraine, where climatic factors are suitably combined with the presence of various mineral waters and ecologically clean environment. Fore-Carpathian region rightfully bears the «burden» of one of the most developed resort regions of Ukraine, where Truskavets is a diamond with the world famous «Naftusya» waters. The glory of radon water resort «Khmilnyk» is spread far beyond the Vinnitsa region.

Why it is special and Why it is good for our well-being?

Underground mineral waters are being formed through interaction of juvenile sedimentation or meteoric waters with the rocks.

Therapeutic mineral waters include groundwater with curative effects on the human body due to primary ion-salt, gas composition, high content of bioactive components or specific properties. Those resorts are to be called spa that contain natural mineral water sources. Mineral waters are used internally for body therapy at drinking resorts, and for external use in the form of general and local baths and showers. Depending on the therapeutic mineral water properties, the purposes for balneotherapy are defined.

Use of the resource

The main institution in Ukraine, which has been studying the effect of mineral water on human health and adopts recommendations on the use of various sources for medical purposes, is Ukrainian Research Institute of Medical Rehabilitation and Balneology of the Ministry of Health of Ukraine in Odessa. The chemical composition and directions of mineral drinking water use are regulated by the state standard of Ukraine DSTU-878-93 «Drinking mineral waters».

The hydro-mineral wealth of Ukraine is determined by availability of acidulous, sulfide, radon, iron and arsenic, iodine, bromine and iodine-bromine, boric, siliceous mineral waters, the waters with high organic matter content, and waters without specific components and properties.

The main resorts of Ukraine and their use are listed below.

Berdyansk (Azov Sea coast, Eastern Ukraine) - spa resort. Natural therapeutic factors: mineral chloride sodium iodine, bromine water; low mineralized chloride sodium mineral water «Berdyansk». Purposes: diseases of the genitourinary system, metabolic disorders.

Berezivski Mineral Waters (Kharkiv region, North-Eastern Ukraine) – drinking water resort. Natural therapeutic factors: hydrocarbonate, different cationic composition with high content of organic substances, silica waters. Purposes: diseases of the gastrointestinal tract, liver, metabolic disorders, diseases of circulatory, respiratory, endocrine, genitourinary, musculoskeletal and nervous systems.

Myrgorod (Poltava region, North-Eastern Ukraine) - drinking water spa resort. Natural therapeutic factors: low-mineralized chloride sodium water, mineral iodine-bromine chloride sodium brines. Purposes: diseases of the digestive, metabolic, circulatory, respiratory, musculoskeletal, nervous, endocrine, genitourinary, skin diseases.

Morshyn (Fore-Carpathians, Western Ukraine) – spa resort. Natural therapeutic factors: sulfate, chloride, sulfate, chloride sodium sulfate, magnesium-sodium brines. Purposes: chronic diseases of the digestive, circulatory, respiratory, musculoskeletal, nervous, urinary, endocrine and metabolic disorders.

Nemyriv (Vinnytsya region, Central Ukraine) – spa resort. Natural therapeutic factors: sulfate, bicarbonate-sulphate calcium waters of low salinity. Purposes: diseases of the nervous and cardiovascular systems, digestive, musculoskeletal, urogenital and endocrine systems, skin diseases.

Odesa (Odesa region, Southern Ukraine) – balneo-mud resort that includes a group of sites: Kuyalnik, Lermontovskiy, Arkadia, Velykiy Fontan, Chornomorka, Karolino-Bugaz, Zatoka, Prymorskiy. Natural therapeutic factors: mineral water sodium chloride, bicarbonate-sulfate-chloride sodium, chloride sodium with high content of metasilicic acid that are used for internal and external use. Purposes: diseases of the digestive system, musculo-skeletal system, damage to the central and peripheral nervous systems, cardiovascular, respiratory, urogenital and endocrine systems.

Polyana (Transcarpathians, Western Ukraine) – spa resort. Natural therapeutic factors: carbonic, boric hydrocarbonate sodium waters of Polyana deposit – the «Polyana Kvasova» and «Polyana Kupel» grades. Purposes: chronic diseases of the digestive system, metabolic disorders, cardiovascular diseases, respiratory, musculoskeletal, nervous, endocrine and urogenital systems.

Truskavets (Fore-Carpathians, Western Ukraine) – the oldest spa resort. Natural therapeutic factors: Truskavets deposit «Naftusya» - hydrocarbon-sulphate-calcium-magnesium bicarbonate low-mineralized water with high content of organic substances. In Bystrivske deposit, strong iodine-bromine, sulfate-chloride magnesium-sodium brines with high content of orthoboric acid are used for «Barbara» salt production.

Ukraine

Purposes: diseases of the digestive system, metabolism, digestive system, circulatory, respiratory, musculoskeletal, nervous and endocrine systems.

Khmilnyk (Vinnytsya region, Central Ukraine) – spa resort. Natural therapeutic factors: mineral radon waters of Novohmilnytske and Khmilnytske deposits («Resort» and «Golodkynska» blocks) are characterized as low-mineralized, low-radon to intermediate-radon hydrocarbon-magnesium-calcium mineral waters. Purposes: diseases of the musculoskeletal system, rheumatic diseases, cardiovascular diseases, diseases of the nervous and endocrine systems, skin diseases.

The heat which is being naturally generated in subsurface of the Earth is one of unconventional forms of energy. It is called geothermal resources and divided into the heat of underground water and heat of the rocks. Thermal waters in most cases are enriched in soluble micro-components such as bromine, boron, iodine, making them valuable spa and industrial raw materials. They are found in the Black Sea, Transcarpathian and Dnipro-Donetsk artesian basin.

In Transcarpathian region, the Beregivske deposit is distinguished to be the thermal water type and it is operating since 1973 in recreational purposes to fill up the swimming pool.

Threats and protection

The mineral water, like any other groundwater may be contaminated and depleted under the influence of anthropogenic factors. Protection of mineral waters from pollution depends on hydrological conditions of deposits, lithological features of the rocks, hydrodynamic characteristics of water-containing sediments and technological factors that may have various origin and properties. Especially dangerous is pollution of household origin. The liquid substances cause greatest threat to underground mineral water pollution.

The groundwater quality change forecasts under influence of anthropogenic factors are of primary importance. In turn, the forecast studies must be based on standardization of mineral waters with regard to their natural protection against pollution that allows the problem articulation and definition of direction to forecasting research.

Myths or stories

In Ukraine the oldest use of underground mineral waters is known from Crimea during the Bosporus Kingdom (2 thousand years ago). The ruins of the well along with the remnants of the ancient Greek temple of God of Treatment – Aesculapius are preserved until now. There is evidence that the mineral springs in Transcarpathians were known as far back as the XVI century.

The first mention of Truskavets resort refers to 1469 while the healing properties of water were described for the first time in 1578 by the Royal Doctor Wojciech Ogko.

The broad use of mineral water in Ukraine began in the XIX century. The discovery of deep groundwater near Truskavets refers to 1820, and the first small baths were built in 1827. The chemical studies of mineral water «Naftusya» had been conducted by Lviv pharmacist Theodore Torosevych. In 1836, Doctor Maliuk gave a description of therapeutic properties of mineral water at this resort. Mineral waters of «Naftusya» type and their medicinal properties are studied up to now.

Geoinform of Ukraine

Natalia Pyshna is the hydrogeologist and Head of Division for Groundwater Resources in SRDE «Geoinform of Ukraine», which maintains the State Cadastre of groundwater, therapeutic mud and brine deposits and occurrences, State recording of groundwater use, including thermal and mineral waters. She has considerable practical experience in the field of groundwater exploration and exploitation in Ukraine.

Boris Malyuk is Dr. Hab. geologist and Director of Centre for International Cooperation in SRDE «Geoinform of Ukraine».

United Kingdom

Introduction

In the UK, groundwater provides a significant proportion of the public water supply (up to 70% locally). Groundwater classified as mineral or thermal waters is often promoted as benefiting our well-being, over and above providing a vital water resource. Where some of these waters emerge as springs at the ground surface, they have historically been important sites for bathing or drinking.

In the UK, thermal water (warmer than the 10-12°C average annual air temperature) is uncommon because the crust in this part of the world is cold, with no significant tectonic activity. Water can be heated naturally if it travels to great depths, where the earth's temperature is higher, or through rocks that emit their own heat. However, there are few pathways to bring warm water to the surface. Only one natural thermal bathing spa exists in the UK today, at Bath in southwest England.

Bottled mineral waters have become increasingly popular in the last 30 years, however. Bottled waters are sourced from across the country and from different geological formations, resulting in varying tastes. The taste derives from the composition of the water. The composition is strongly dependent on reactions with the host rocks and on the length of time it has spent within them. Therefore, mineral and thermal waters are intimately linked with geology.

Why it is special and why it is good for our well-being?

Over history, thermal and mineral waters have been considered beneficial for health, from the very early civilisations through to more recent times. Before modern medicine, mineral and thermal waters were used to treat a great variety of ailments, from infertility to gout (Robins & Smedley, 2013). Health tourism was popular in Roman-occupied Britain and entered a renaissance in the 1700s and 1800s, when people would travel across the country to 'take the waters' (for bathing or drinking) (Downing, 1998).

Health benefits were generally believed to be attributed to the many and varied dissolved minerals within the waters. Water rich in magnesium and sulphate (Epsom salts) was popular as a laxative in the 17th century. Apart from causing a general purging of the body, it would also reduce side effects from treatments such as Venice Treacle, a preventative for the plague. Nonetheless, it is likely that the greatest benefit conveyed by these waters was as a vital source of clean water, or as a placebo cure (Robins and Smedley, 2013). There is some evidence that bathing in spring waters can help to ease rheumatism (joint pain), though it is difficult to separate medicinal properties from the more general effects of hydrotherapy. Thermal waters are now used for relaxation.

Use of the resource

'Taking the waters' has much declined in the UK since the 19th century, but this has been superseded by the bottled water industry. Many people consider drinking bottled mineral water preferable to tap water because it is minimally treated (not disinfected) and so perceived to taste better. The practice of bottling and selling of mineral waters first became popular in the 1900s for the rehabilitation of soldiers from World War 1. Nowadays, over 2 billion liters of bottled waters are produced by the UK each year, 1.4 billion liters being natural mineral water abstracted from 65 different UK sources (BSDA, 2014, DEFRA, 2014). However, the average consumption of bottled water of 37 liters per person per year in the UK is much lower than the European annual average of 115 liters per person. The rise of the bottled water industry should be viewed in the context of growing environmental concerns over food miles and waste (bottle) disposal.

Most bottled mineral waters in the UK originate from minor aquifers in older rocks (nearly 50% of sources originate from rocks more than 300 million years old) and often in uplands (Smedley, 2010). A number of UK mineral waters are world-famous. For example: Malvern water, west England, flows through fractures in ancient igneous rocks and is known for its low solute content. It was prescribed by the National Health Service until this was stopped by cost-cutting measures in 1993 (Robins & Smedley, 2013). Harrogate waters, north England, emerge as springs from a complex aquifer system in deformed Carboniferous rocks. Close to 100 springs associated with the source have differing compositions, depending on the residence time of the water in the underground system (Downing, 1998).

Thermal waters in the UK have usually travelled via fractures to great depths in the earth's crust where they are heated by earth's heat energy. This is a slow process, so the emerging thermal waters are usually very old. Some 1.25 million liters per day flow from three thermal springs to supply the thermal spa at Bath, with an average temperature of 46.5 °C (Atkinson & Davison, 2002). This water infiltrated into the rocks of the Mendip Hills to the south of Bath some 10,000 years ago, circulating to 3 km depth, probably flowing back to the surface via a geological fault. The cooler thermal waters at Buxton, north England (27 °C) (Smedley, 2010), and Taff's Well, Wales (21 °C) (Farr, 2014) no longer supply spas but still yield 1 million and 87 thousand liters per day respectively, with waters estimated to be 5,000 years old.

United Kingdom

Threats and protection

As with any groundwater, bottled mineral water resources are dependent on rainfall. In the exceptionally dry year of 2006, the Malvern Spring stopped flowing altogether. Subsequent rainfall flowed too quickly through the fractures to be adequately filtered, requiring installation of filtration equipment and losing the water its natural mineral water status (Connell, 2007). While such responsiveness to rainfall is an extreme example, long term changes in precipitation (due to climate change, for example) might affect the availability of other bottled water resources.

Over-abstraction of groundwater resources from major aquifers is unlikely to pose a major threat to bottled water resources, since the latter are generally sourced from minor aquifers. Some local laws exist to protect the immediate vicinity around sources such as the Bath Springs. Government agencies responsible for the environment license groundwater abstractions for use from aquifers, though this authority does not extend to dewatering for mine or quarry works. In this case, planning regulations might protect groundwater sources. However, there is concern in Bath that local quarry dewatering could reduce the temperature or flow of the thermal springs (Atkinson & Davison, 2002).

Pollution measures to protect mineral water springs are stringent because natural mineral water cannot be treated or altered, and protection zones can cover vast areas of land. Rules regarding the protection of mineral water springs are detailed in The Natural Mineral Water, Spring Water and Bottled Drinking Water Regulations 2010 (England; SI433; based on European Commission Directives 2009/54/EC and 2003/40/EC).

Myths or stories

Mineral and thermal waters have a mystique that has rendered them sacred throughout the ages. One of the most notorious tales is of the discovery of Bath spa by Prince Bladud, who was later to become the mythical God-King, father to King Leir (or Lear, in the Shakespeare play). The young Prince was banished from his father's Royal Court after contracting Leprosy. Whilst working as a swine-herdsman he noticed that his pigs enjoyed wallowing in the hot muddy waters around Bath, but also did not have common skin diseases. Prince Bladud began to bathe with the pigs and found himself cured. He returned to the Royal Court and founded the city of Bath in 863 BC. Bath has remained popular, being the location of the Roman 'Aquae Sulis', a sanctuary within a sophisticated series of baths with a temple to Goddess Sulis Minerva, and was a source of archaeological wonder into the Saxon era and Middle Ages.

British Geological Survey

Sian Loveless is a hydrogeologist at the British Geological Survey. Her research interests include faults and fluid flow, hydrogeological rock properties and geothermal energy.

Pauline Smedley is a hydrogeochemist with the British Geological Survey, with interests in the chemistry of groundwater and drinking water and the processes that determine it.

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