Introduction to ‘Groundwater for wellness’

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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^{o}C in Northern Europe to over 103^{o}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 litres 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 Litres 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 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 ($Ca\text{-}HCO_3$) 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 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.

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.

Major ions > 5 mg L^{-1}	Bicarbonate	Chloride	Sulphate
	Sodium	Calcium	Magnesium
Minor ions 0.01-10.0 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 (Hiscock, 2005)

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)

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. 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.

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