



General ground water geochemistry of Hellas using bottled water samples

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ABSTRACT

Sixty-one still bottled water samples, representing 41 locations, were collected from Hellas for the purpose of studying the geochemistry of ground water. Since, the dominating lithology comprises limestone, dolomitic limestone, marble, and mafic-ultramafic rocks (ophiolites), the dominant major ions in Hellenic bottled waters are Ca^{2+} , Mg^{2+} , CO_3^{2-} and HCO_3^- , and are, thus, classified in the Ca^{2+} - Mg^{2+} - HCO_3^- hydrochemical facies. The source aquifers of Hellenic bottled water are apparently continuously replenished by fresh water. Comparison of values of Ca, Mg, K, Na, Cl^- , HCO_3^- , NO_3^- , SO_4^{2-} , pH and electrical conductivity, displayed on bottle labels with those of this study, has shown that there is a fairly good correlation between the two data sets, suggesting that the geochemistry of source aquifers is relatively stable over time, at least from 1998 to 2008.

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1. Introduction

Hellas is a country with a diverse geology and climate, but also of mythology and ancient rituals with spring and river water. In ancient Hellenic culture, water was not only associated with hygiene and the needs of the human body, but it became an essential part of religious ritual, ensuring the soul's well-being through the metaphorical concept of catharsis (Chrysoulaki, 2010; Håland, 2009). Water was always a part of purification ceremonies, initiation rituals, cures and acts of divination, even conversing with immortality. In myths and fables, heroes searched in vain for the water of life, the 'immortal water', to quench the waterless desert of death. Water makes the earth fertile and the land hospitable. Hence, from prehistoric to the present time, water has guided people's steps, the sites for their settlements, contributed to the management of agricultural activities and survival of their livestock. Rivers and springs became the places near which the first settlements were built, and the benevolence of water allowed cities and their civilizations to flourish. In the imaginative rich world of popular beliefs and symbols, the changeable nature of river courses gave rise to images of powerful and unpredictable daemons capable of continuous change in form, offering in the one hand abundance and in the other threatening with disaster (Chrysoulaki, 2010). Conversely, spouting springs and tranquil lakes were inhabited by youthful girls, the 'naiads' (water nymphs). Holy water is also part of deep Christian traditions, associated with Virgin Mary under her attribute of 'Life-giving Spring' (Zōōdhóchos Pegé), but also with other Saints (Håland, 2009).

In Hellas there are areas blessed with water and others that are not. Climatic change is, in fact, affecting Hellas to a variable degree. This has been observed quite evidently in the bottled water industry, where natural spring water is used for bottling. Up to now two bottling companies have closed down, the first in Thrace in north-east Hellas, and the second in south Peloponnese. The reason in both cases was the reduced capacity of the natural spring. It is here very relevant to quote Benjamin Franklin (1706–1790) "We will only know the worth of water when the well is dry". However, ground water resources are still available in areas of Hellas with a comparatively high rainfall. Hence, because of the increased demand for bottled water, new companies have started operations in these areas.

The length of the Hellenic coastline is 13,780 km, and most of it is due to the 6000 islands and islets. Many of the inhabited islands do not have good quality potable water supply, and the islanders rely on bottled water for drinking and cooking, e.g., Aegina, some of the Cyclades and Dodecanese Islands, Zakynthos, an Ionian Sea island, etc. There are also some areas on mainland Hellas that resort to bottled water, because of the poor quality of their ground water resources, e.g., Argholidha (north-east Peloponnese) and Thessaly (eastern central Hellas), because of high nitrates, and some parts of Elia Prefecture (north-west Peloponnese) due to elevated concentrations of iron and manganese.

The consumption of bottled water in Hellas was 380 million litres in 1998, it reached 627 million litres in 2003, and in 2005 was up to 1 billion litres. It appears that the consumption of bottled water increases by about 10–12% per year. On average, the consumption was 45 L/person in 1998 and by 2009 it reached over 100 L/person. The greatest consumption is, of course, during the summer period with the hundreds of thousands of tourists.

To set up a bottled water industry a permit is required from the Health Department of the Prefecture for table water, whereas for

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mineral water from the Ministry of Health. Hence, the difficulty of finding out all bottled water brands available on the Hellenic market, since some of them are very local. The Mineral Water Organisation lists 31 Hellenic brands (<http://www.mineralwaters.org/>). Whereas, in accordance with Article 1 of Directive 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on “the exploitation and marketing of natural mineral waters” (EU, 2009), there are only 38 natural mineral waters recognised officially by Hellas. Nevertheless, there are more brands on the market, and a conservative estimate is about 65 bottled water companies are operating in different parts of the country.

The present paper describes the general geochemistry of ground water sources of Hellenic bottled water, then compares the results of this study with those displayed on bottle labels, and finally discusses concisely the overall geochemical characteristics of ground water using as a ‘proxy’ Hellenic bottled water samples. It is stressed at the outset that it was never the intention of this project to assess the quality of bottled water, since for such an assessment many more parameters should have been analysed, and specifically organic compounds and microbiological components (refer to Fotiou and Kolovos, 2004). Also, a separation of Natural Mineral Water from Natural Bottled Drinking Water (often called Table Water) should

have been made, because each has to comply with a different legislation, i.e., EU Directive 1998/83/EC (EU, 1998) and EU Directive 2003/40/EC (EU, 2003), respectively. However, since readers may be interested in the quality of Hellenic bottled water, it can be safely stated that the concentrations of determined inorganic parameters are below the recommended statutory guideline values. The analytical data of this study are included on the CD-rom accompanying the atlas of the “Geochemistry of European Bottled Water” (Reimann and Birke, 2010).

2. Methodology

2.1. Sampling and analysis

In this project a total of 61 still bottled waters were purchased from supermarkets, representing 41 different locations (Table 1); 57 bottled waters were in soft polyethylene terephthalate (PET) and four in clear glass bottles; eight PET bottles were duplicates, purchased from different supermarkets, and another eight were from the same location, but marketed under a different brand name. Apart from the duplicate bottles that were used for quality control purposes, three different brands of water for injection were

Table 1
Hellenic bottled waters analysed in this study. The star (*) denotes natural bottled mineral water listed in Directive 2009/54/EC (EU, 2009). The others are classified as Table water. In brackets are given bottled waters from the same location, but marketed under a different brand name (see Fig. 1 for their location).

| Sample number | Brand name | Name of spring/borehole | Bottling location |
|---------------|---|-------------------------------------|---|
| 1 | Vikos* | Vikos | Fteri Perivlepour, Ioannina Prefecture |
| 2 | Zagori* | Zagori | Kranoula, Ioannina Prefecture |
| 3 | Korpi* | Korpi | Korpi, Monastiraki, Akarnanika Mts., Vonitsa, Aetoloakarnanias Prefecture |
| 4 | Ioli* | Ioli | Moschochori, Fthiotida Prefecture |
| 5 | Sariza | Sariza | Apikia, Andros Island, Cycladhes Prefecture |
| 6 | Avra* | Avra, Aegion | Aegion Municipality, Achaia Prefecture |
| 7 | Aqua Vita | Aghia Varvara, Rhodes I. | Aghia Varvara, Rhodes I., Dodekanisssos Prefecture |
| 8 | Pindos | Ziaka Grevena | Grevena, Grevena Prefecture |
| 9 | Samarina* | Goura Samarinas | Samarina, Grevena Prefecture |
| 10 | Drosoula | Roditi | Roditi Spring, Kozani, Kozani Prefecture |
| 11 | Nera Kritis | Foot of White Mountains | Varipectro Therisso Chania, Crete I., Chania Prefecture |
| 12 | Mythical | Psiloritis Mountain | Psiloritis, Crete I., Heraklion Prefecture |
| 13 | Rouva's | Gegeri, foot of Psiloritis Mountain | Gegeri, Heraklion, Crete I., Heraklion Prefecture |
| 14 | Samaria | Stylos | Stylos, Foot of White Mountains, Crete I., Chania Prefecture |
| 15 | Lytos | Chomoprina, Malia Municipality | Coca Cola 3E, VIPE, Iraklion, Crete I., Chania Prefecture |
| 16 | Gortys | Asterousia Mountains, Aghia Marina | Lendas, Crete I., Heraklion Prefecture |
| 17 | Zaro's* | Amati, Psiloritis Mt. | Heraklion, Crete I., Heraklion Prefecture |
| 18 | Rizitiko | Psiloritis Mountain | Heraklion, Crete I., Heraklion Prefecture |
| 19 | Krini | Dikti Mountains, Crete | Kasteli, Pediados, Heraklion Prefecture |
| 20 | Dikti | Baboulani, Dikti (Lasithi) | Crete I., Lasithi Prefecture |
| 21 | Kimi* | Honeftiko (Kimi) | Honeftiko, Kimi, Euboea I., Euboea Prefecture |
| 22 | Eviva (Gargaro, Mitsikeli, Marata, Physiko Nero AB) | Sepeta | Kalpaki, Ioannina Prefecture |
| 26 | Loutraki* | Loutraki | Loutraki, Korinthia Prefecture |
| 27 | Loutraki Hydria | Loutraki | Loutraki (Hydria), Korinthia Prefecture |
| 28 | Loutraki Karadanis Provis | Loutraki | Loutraki, Korinthia Prefecture |
| 29 | Loutraki Ivi | Gerania Mountains | Loutraki, Korinthia Prefecture |
| 30 | Iris Loutraki | Loutraki | Loutraki, Korinthia Prefecture |
| 31 | Hydor Sourotis* (Daily Drink Water) | Anthemia (Anthemounda Basin) | Souroti, Thessaloniki Prefecture |
| 33 | Athos (Iro) | S. Platani (Poligiros) | Akonorachi, Poligiros, Chalkidhiki Prefecture |
| 34 | Evdoro* | Evdoro | Evdoro, D.D. Mexiatate, Municipality of Ipati, Fthiodidha Prefecture |
| 35 | Tzoumerka | Agathi Melissourgon | Melissourgoi, Arta Prefecture |
| 36 | Velouhi | Kefalovrisso Aghia Triadha | Velouhi, Evritania Prefecture |
| 37 | Seli* | Assos, Vermion Mt. | Spilia, Vermion Mountain, Kozani Prefecture |
| 38 | Pigi Paikou | Axioupolis | Axioupolis, Paiko Mountains, Kilkis Prefecture |
| 39 | Krinos* | Anastassopoulou spring | Rododafni Aegio, Achaia Prefecture |
| 40 | Zefiros | Zefiros, Achaia Mountains | Chondrolongos, Rio Municipality, Achaia Prefecture |
| 45 | Hyas* (Krinea) | Kaliani | Kaliani, Korinthia Prefecture |
| 46 | Beles (Aqua) | Angistro | Angistro, Serres Prefecture |
| 47 | Klinos* | Palavi | Klinos Community, Pindos Mts., Trikala Prefecture |
| 48 | Vitsi | Florina springs | Florina, Florina Prefecture |
| 49 | Drossia | Drossia | Mt. Kaimaksalan, Imathia Prefecture |

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