15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. **7** Ext. Abs. GSG2019-107

The Use of Environmental Stable Isotopes at the Tirnavos Alluvial Basin (Central Greece)

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Introduction

Oxygen and hydrogen isotopes are widely used as conservative groundwater tracers because their values remain constant as long as there are no phase changes or fractionation along the flow path (Clark and Fritz, 1997). The isotopic composition of precipitation depends on local conditions and various environmental factors such as temperature, distance from the sea or continentality, latitude, altitude, amount and season (Sharp, 2007). The composition of these tracers reveals useful information such as the origin and mixing of groundwater, the degree of mixture of surface, meteoric and ground water, the salinization of groundwater and others. $\delta^{18}O$ values can be used to identify the source of groundwater, as well as to determine the mean altitude of recharge (Matiatos *et al*., 2010). In order to facilitate interpretation of data the expected mean $\delta^{18}O$ value of direct recharge at the local altitude can be plotted (Leibundgut *et al*., 2011).

Geological-hydrological characteristics

Tirnavos sub-basin forms the north-eastern part of the eastern Thessaly plain of Central Greece. It is filled by Quaternary alluvial deposits that are bounded along the SW part of the basin by Neogene marls and sandy-clay deposits. At the western margins karstified marbles of middle-upper Cretaceous crop out. The crystalline bedrock of the Pelagonian unit composed by Mica-schists of Upper Paleozoic and Gneisses of Paleozoic age form the northern boundary of the sub-basin (Figure 1). Two major springs emerge at the contact of the karstified system with the alluvial deposits. Pinios and Titarisios Rivers flow across the sub-basin which hydrologically is part of the Pinios River Basin. The Quaternary deposits host an unconfined aquifer near the talus cones of Titarisios at NW, which towards the central parts of the basin converts to a system of a phreatic and a deeper confined aquifer, separated by a sequence of clay layers (Panagopoulos, 1996). Despite the limited potential of the phreatic aquifer nowadays, its importance is paramount as it forms an effective buffer zone that protects the confining units from deep percolation of anthropogenic origin pollutants, especially of agricultural origin. Also, the marbles of the west margin of the basin host a karstic aquifer of great potential. This karstic aquifer and the Titarisios River are the main recharge sources of the alluvial basin aquifer system. Agriculture is the dominant land use in the study area, covering approximately 16.000ha (71% of the gross area) (Alexandridis *et al*., 2014).

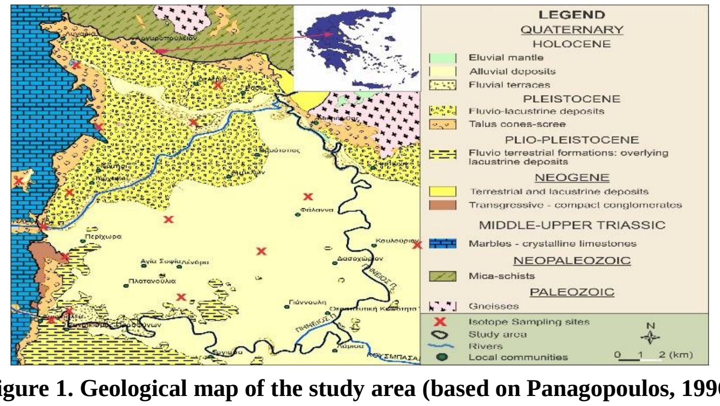

Figure 1. Geological map of the study area (based on Panagopoulos, 1996)

Methods and Results

The purpose of this study is to examine the isotopic composition of the typical alluvial aquifer system of Tirnavos sub-basin and compare it with the isotopic composition from previous studies for the wider region. Sampling was performed at April (isotope and hydrochemical analyses) and September (isotope analyses) of 2018, that are representative for the dry and wet hydrological periods, respectively. Sampling network consisted of 34 wells, 2 springs and 6 surface water sites from Pinios and Titarisios Rivers. Fifteen (15) and eleven (11) samples were collected for isotopic analyses over the first and second periods, respectively. Based on the analytical results, the Local Groundwater Isotope regression Line (LGIL) was compiled and plotted along with the Global MWL, Greek MWL and Thessaly MWL, as depicted in Figure 2A. Isotope values of $\delta^{2}H$ and $\delta^{18}O$ are expressed as the difference between the measured ratios of the sample and reference divided by the measured ratio of the reference, which is expressed as the VSMOW values (Vienna-Standard Mean Ocean Water). The isotopic ratio of $\delta^{18}O$ in the study area ranges between -9.8‰ and -6.9‰ with an average value of -8‰. This value almost coincides with the average value recorded from spring waters of Thessaly which is -8.29‰ (Dotsika *et al*., 2010). Similarly, the isotopic ratio of δ^2H ranges between -66.2‰ and -47.5‰ with an average value of -51.3‰ which is almost the same with the average value recorded in Thessaly which is -51.1‰, on the basis of the aforementioned reference. Based on these observations, the isotope composition of groundwater for Tirvanos sub-basin seems to fit perfectly with the obtained levels from the previous study on Thessaly region. The function that express the LGIL which is $\delta^2H=6.71\delta^{18}O +2.09$ compared to Thessaly MWL ($\delta^2H=6.48\delta^{18}O +1.7$) presents similar slope (6.71 and 6.48) and little higher value of the d-excess (2.09 and 1.7). Generally, the deuterium excess is primarily controlled by kinetic effects associated with evaporation of water at the surface of the oceans or inland and increases with an increase in the moisture deficit of the oceanic air masses (Sharp, 2007). Differences in d-excess arise as a consequence of varying temperature, relative humidity and wind speed at the sea surface, where global atmospheric moisture mainly originates, as well as from admixture of recycled continental vapour (Dotsika *et al*., 2010, Tziritis, 2011). Hence, the value of d-excess (close to 2) in the study area compared to the GMWL value (10) could probably be attributed to the environmental conditions. The projection of δ^2H and δ^{18}O ratios for surface and ground waters in a common plot (Figure 2B) defines the Local Surface Isotope regression Line for the study area (y=5.06x-9.95). Although the number of surface water sites could have been larger, the slope of the regression line (5.06) and the d-excess value (-9.95) do indicate the effect of the evaporation on these surface receivers. It could also be argued that due to the difference in the isotopic ratio between groundwater and surface water, there seems to be no (or not significant) hydraulic interaction between them.

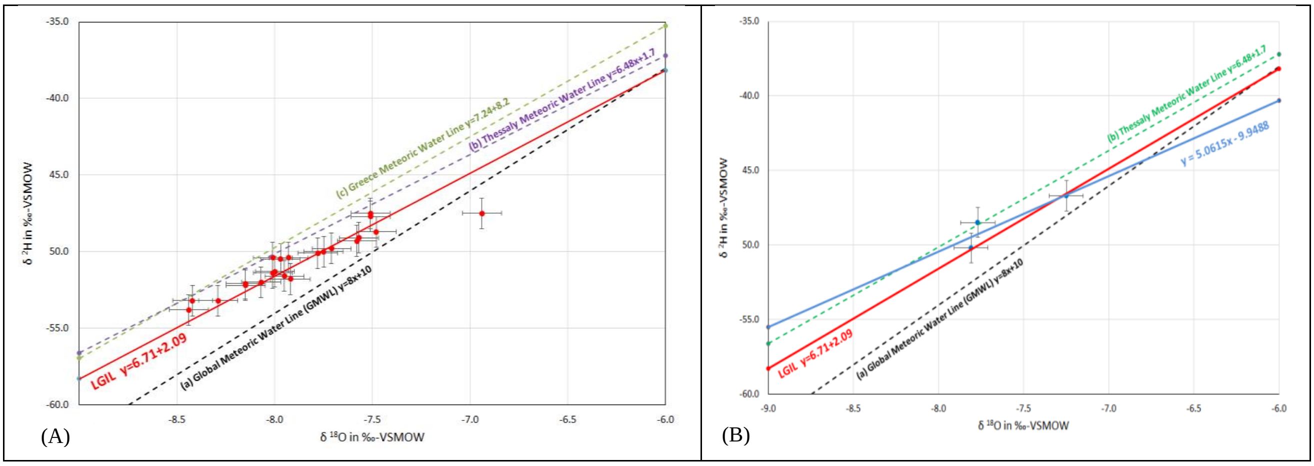

Figure 2. (A) Local Groundwater Isotope regression Line (Tirnavos sub-basin) along with (a) GMWL (Craig, 1961), (b) Thessaly Meteoric Water Line (Dotsika et al., 2010) (c) Greece Meteoric Water Line (Argiriou & Lykoudis, 2006) (B) Local Groundwater Isotope regression Line compared to Local Surface Isotope regression Line (blue line)

Conclusions

The isotopic composition of Oxygen (^{18}O) and Deuterium (^{2}H) were defined for the alluvial aquifer system of Tirnavos sub-basin. For this purpose, totally 26 samples for both groundwater and surface waters were collected in two sampling periods. Results were plotted and the Local Groundwater Isotope Line and Local Surface Isotope Line were compiled. The slope and the d-excess values compared to the Thessaly Meteoric Water Line (Dotsika *et al*., 2010) showed no significant deviations; thus, demonstrating that the study area follows the general composition of the wider region isotopic ratio. The low value of d-excess compared to the GMWL value may be attributed to the environmental conditions. Regarding to the Local Surface Isotope Line, the slope of the regression line and the d-excess value show the effect of the evaporation on these surface receptors.

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