HYDROGEOCHEMICAL ASSESSMENT OF THERMAL WATER IN FRACTURED ROCKS – A PORTUGUESE CASE STUDY

Antunes IMHR[1,3], Albuquerque MTD[2,3], Mota Pais M[2]

[1] ICT / University of Minho. Campus de Gualtar, 4710-057 Braga, Portugal
[2] Instituto Politécnico de Castelo Branco, Castelo Branco, Portugal
[3] CERENA/FEUP Centre, Portugal

Abstract

The thermal Fadagosa-Nisa water is located at north Alentejo (Portugal) and it is important in the economy of this region. The studied area is in a predominantly fractured granite and the water circulation is characteristic of fissured media, with a productivity of 2 L/s from a single well. Water hydrogeochemistry results revealed a mineralized water, with an electrical conductivity of 454 µS/cm and a total mineralization of 310 mg/L, neutral (pH=7.9-8.0) and a temperature of 19ºC. The thermal water has a dominant hydrogeochemical sodium-bicarbonate facies, with a fluoride (F^-=9.6 mg/L) and hydrogen sulphide content (HS=15.2 mg/L), and moderate amounts of silica (SiO_2=34.0 mg/L). The low nitrate (NO_3^-=0.1 mg/L) and sulphate (SO_4^{2-}=1.6-5.2 mg/L) contents support the low vulnerability associated to the groundwater catchment. No significant seasonal changes have been found in the Fadagosa-Nisa thermal groundwater composition, suggesting a hydrogeochemical stability to the area. The regular hydrogeochemical results is in accordance to the low vulnerability obtained by the application of DRASTIC index in the Fadagosa-Nisa area.

Keywords: groundwater; aquifer vulnerability; thermal water; hydrogeochemistry; Portugal.

1. INTRODUCTION

Portugal is one of the richest countries considering the huge number and variety of natural springs, some of them known since ancient times and recognized due to its medicinal properties (Lepierre 1930). Thermal mineral waters are a potential resource in the economic development of a region. The thermal waters of Fadagosa-Nisa have an important role on the local economy and on its community welfare due to the therapeutic properties, particularly the skin diseases treatment. The thermal activities date back to the eighteenth century as suggested by the construction of the first buildings in 1792 (Figueiredo 1956). However, since then, the activities have not been steady along the years, alternating the active development, with decline and abandonment. The first contract, aiming the natural mineral water exploitation for a period of 50 years, was signed in 1992, thereby the first protection perimeters for the thermal catchment were created through the delineation of three zones of influence: immediate, intermediate and broad protection areas (Diário da República 1992).
The objective of this study was to characterize the hydrogeology and hydrogeochemistry of Fadagosa-Nisa thermal water, aiming a better understanding of hydrogeological groundwater fractured systems.

2. FADAGOSA-NISA THERMAL AREA

2.1. Hydrogeological setting

The thermal mineral water from Fadagosa-Nisa is situated in the NE of the Alentejo region, 9 km southwest of Nisa, northern Portalegre, Central Portugal (Fig. 1a; b). The studied area is included in the Variscan Massif, Central Iberian Zone, showing an intense fracturation due to the compressive tectonic movements during the Variscan orogeny, Paleozoic.

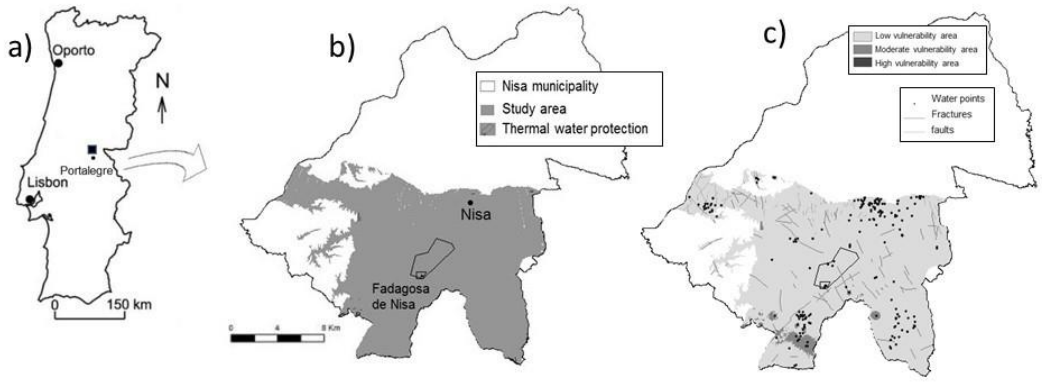

Fig. 1. a) Study area geographical setting; b) Fadagosa-Nisa thermal area; c) vulnerability classes

Geologically, the area is predominantly composed of fractured granites, with fractures often filled with clay materials (Mota Pais 2011).
The underground water productivity of the rocks from the Variscan massif is locally and highly controlled by geological structures, whereby the mineral waters are directly conditioned by regional fracturation (Carvalho 1996). In these formations, relevant discontinuous systems occur and water circulates predominantly through these discontinuities (Almeida et al. 2000).
At the studied area, the occurrence and movement of groundwater is mainly controlled by fractures and other discontinuities (Fig. 1c).
The groundwater catchment of Fadagosa-Nisa is located in a slightly watered granite, highly fractured, belonging to the Igneous Rocks water sector, which is filled by secondary clays. The average productivity is approximately 2 L/s (well ACP4), indicating a poor water unit's capacity and showing specific features of a fissured water system. Extensive farming and extensive livestock production are the dominant activities in the area and, consequently, the potential source of negative impacts on groundwater quality (Mota Pais et al. 2012).
The thermal water characteristics depend on the rocks composition and water residence time. Therefore, it is essential to ensure geological environments' preservation because spatial-temporal evolution influences the thermal water resources. The water quality maintenance is crucial and depends on the vulnerability of aquifer systems (Samake et al. 2011). The DRASTIC index was applied as a methodology for vulnerability characterization of the studied area (Mota Pais et al. 2012). It is possible to identify spots of moderate to high vulnerability, although, around the Fadagosa-Nisa catchment, the vulnerability is low (Fig. 1c).

2.2. Hydrogeochemical assessment

The Fadagosa-Nisa thermal water is an important resource for medical and therapeutic purposes and an important component of community income. The groundwater catchment (ACP4), about 65 m deep, holds an average productivity of 2 L/s.
The thermal water from Fadagosa-Nisa has similar characteristics with other Portuguese waters, corresponding to the main Portuguese thermal units. Granite-related waters are dominated by the HCO_3 anion and Na, Ca and K cations, with an appreciable amount of SiO_2 (20 to 100 ppm). The thermal waters in Portugal, about 52 springs, have emergency temperatures between 20 and 76º C in the north and center of Portugal, due to their lithological and structural characteristics (Marques 2012).
The main features of the Fadagosa-Nisa thermal water are a temperature of 19ºC and a neutral pH value (pH = 7.9-8.0). These values are in the pH range of most groundwaters (pH= 6-9). The thermal water has an electrical conductivity of 454 µS/cm and a total mineralization of 310 mg/L.
The thermal water also has substantial amounts of silica (SiO_2 = 34.0 mg/L), fluoride (F^- = 9.6 mg/L) and hydrogen sulphide contents (HS = 15.2 mg/L).

According to Piper classification, the thermal water is of the sodium bicarbonate type (HCO_3^- = 151.5 mg/L; Na = 98.5 mg/L). The low nitrate (NO_3^- = 0.1 mg/L) and sulphate (SO_4^{2-} = 1.6-5.2 mg/L) contents support the low vulnerability associated to this groundwater catchment. The waters in the Central Iberian Zone are generally hyposaline and compatible with human consumption (Diário da República 1998). However, the arsenic content in water (As = 26 µg/L) is higher than the maximum reference value for human consumption established by the Portuguese legislation (10 µg/L).
The thermal water composition of Fadagosa-Nisa is stable, as suggested by the obtained water results, between 1990 and 1996, in extreme climatological conditions (Calado 2001). This hydrogeochemical stability supports the reduced vulnerability obtained to the Fadagosa-Nisa area with low values for the DRASTIC index, along the entire hydrological year.
The statistical evaluation of physical and chemical water parameters, determined for 10 years (2000-2010), allowed the temporal variability characterization and the interpretation of possible future impacts, mostly due to seasonal vulnerability. The obtained results indicate no significant seasonal changes for the intrinsic vulnerability parameters, as they tend to remain constant independently of the seasonal period (Fig. 2). However, despite it might be unlikely to expect contamination, the risk monitoring should be a priority procedure as well to take appropriate precautionary measures.

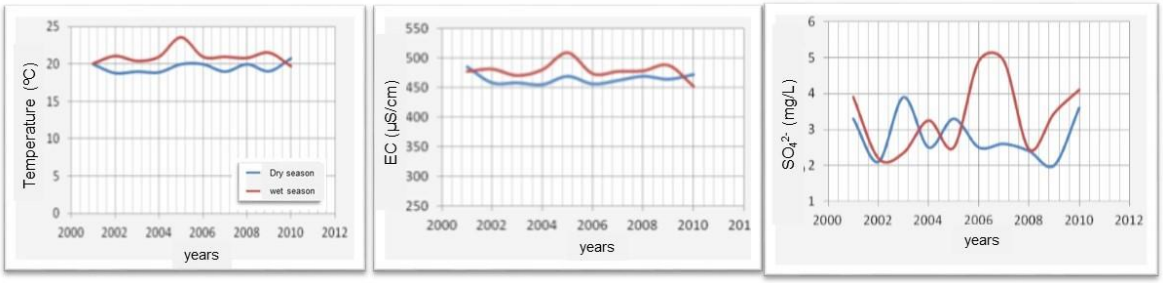

Fig. 2. Seasonal Fadagosa-Nisa thermal water composition

3. CONCLUSIONS

The thermal mineral water from Fadagosa-Nisa is located in a slightly watered granite, highly fractured, showing typical features of a fissured groundwater system. The average productivity is approximately 2 L/s, locally and highly controlled by geological structures.
The Fadagosa-Nisa thermal water is an important resource for medical and therapeutic purposes and an important factor for the community income. Physico-chemical water results revealed a mineralized and neutral groundwater with a dominant hydrogeochemical sodium-bicarbonate facies.
A temporal study of the catchment groundwater composition indicates a hydrogeochemical stability, since no significant seasonal water changes have been found and water composition remain stable, independently of the seasonal period. The stability of water results support the obtained low DRASTIC index values in the Fadagosa-Nisa area.
The Fadagosa-Nisa thermal area occurring in granitic formations with a dense system of faults, associated with the water deep (65 m), has a low vulnerability to the potential contaminant infiltration. Vulnerability assessment is relevant for decision making, concerning territorial planning and local resource preservation and future risk monitoring is a crucial tool for the assessment and management of thermal resources.

Acknowledgments
The author acknowledges the funding provided by the Institute of Earth Sciences (ICT), under contracts UID/GEO/04683/2013 with FCT (the Portuguese Science and Technology Foundation).

REFERENCES

Almeida C, Mendonça JL, Jesus MR, Gomes AJ 2000 Sistemas aquíferos de Portugal Continental. Instituto da Água, Lisboa, Portugal.
Calado CMA 2001 A Ocorrência de água sulfúrea alcalina no Maciço Hespérico: Quadro hidrogeológico e quimiogénese. PhD Unpublished thesis. Faculdade de Ciências da Universidade de Lisboa, Portugal.
Carvalho JM 1996 Mineral water exploration and exploitation at the Portuguese Hercynian massif. Environmental Geology 27, 252-258.
Diário da República 1992 Portaria 948/92 de 29/09/1992; define os perímetros de segurança para a captação das Termas da Fadagosa de Nisa. Lisboa, Portugal
Diário da República 1998 Normas, critérios e objectivos de qualidade da água; DR I-A, 3676-3722, Portugal.
Figueiredo JF 1956 Monografia de Nisa. Imprensa Nacional Casa da Moeda; Câmara Municipal de Nisa, Portugal.
Lepierre C 1930 Chimie et Pysico-Chimie des Eaux (Le Portugal Hydrologique et Climatic), p. 32. Lisbon.
Marques JM 2012 As águas termais: o parente mais nobre das águas subterrâneas de uma dada região. In: Águas minerais naturais e de nascente da região Centro, JAS Cortez (Ed), 71-90.
Mota Pais MFA 2011 Avaliação da vulnerabilidade do sistema aquífero da captação da Fadagosa de Nisa (Concelho de Nisa). Ms Unpublished thesis. Instituto Politécnico de Castelo Branco, Portugal.
Mota Pais MA, Antunes IMRH, Albuquerque MTD 2012 Vulnerability mapping in a thermal zone, Portugal - a study based on DRASTIC index and GIS. Multidisciplinary Research on Geographical Information in Europe and Beyond. Proceedings of the AGILE'2012 International Conference on Geographic Information Science, Jérôme Gensel, Didier Josselin & Danny Vandenbroucke (Eds), Avignon, France.
Samake M, Tang Z, Hlaing W, Ndoh Mbue I, Kasereka K, Balogun WO 2011 Groundwater Vulnerability Assessment in Shallow Aquifer in Linfen Basin, Shanxi Province, China Using DRASTIC Model. Journal of Sustainable Development Vol. 4, No. 1.

Theme I: Thermal and mineral waters in fractured rock environments