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ISBN: 978-989-8509-11-6

10.º SEMINÁRIO SOBRE ÁGUAS SUBTERRÂNEAS

LIVRO DE RESUMOS

ASSOCIAÇÃO PORTUGUESA DOS RECURSOS HÍDRICOS
Comissão Especializada de Águas Subterrâneas
Núcleo Regional do Sul

UNIVERSIDADE DE ÉVORA

10.º SEMINÁRIO SOBRE ÁGUAS SUBTERRÂNEAS

Évora, 9 e 10 de abril de 2015 | Universidade de Évora

LIVRO DE RESUMOS
do 10.º Seminário sobre Águas Subterrâneas

DEMONSTRATING MANAGED AQUIFER RECHARGE AS A SOLUTION TO WATER SCARCITY AND DROUGHT: DESCRIPTION OF MARSOL PROJECT DEMO SITES IN PORTUGAL

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ABSTRACT

This paper presents a synthesis of the work developed in Portugal, by LNEC, TARH and UAlg, for the European Union Seventh Framework Programme project "Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought – MARSOL". The main achievements gathered in the DEMO sites during 2014, the first year of the project, are briefly presented.

Key-words: MAR (managed aquifer recharge); DEMO site experiments; Algarve.

1. INTRODUCTION

The growing imbalance between water supply and water demand in southern Europe, exacerbated by climate change, requires more efficient water resources management. The urgent need for innovative and efficient solutions to save water and energy is clear.

Storing water in aquifers during times of excess can help address water scarcity challenges. Moreover, water quality can be improved through aquifer transport and storage, due to chemical and biological reactions, in addition to the dilution. Managed Aquifer Recharge (MAR) can be a key to solving Europe's water crisis by linking water reclamation, water reuse and water resources management.

In this paper, the work developed in Portugal under MARSOL project is presented. The main objectives of this project are to demonstrate how MAR can contribute as an alternative source of water, in the context of an integrated and inter-annual water resources management, as well as in solving groundwater quality problems. For the case of DEMO Site of Algarve and Alentejo, South Portugal, the water quality problems are mainly caused by inadequate agricultural practices and wastewater discharges.

The alternative water sources explored under MARSOL in Portugal are surface water surpluses generated during rainy seasons and wastewater effluent with secondary treatment. Both are being studied to assess the volumes available and their significance in the regional water budget context, and their quality. One of the aspects being studied is the feasibility of using karstic aquifers as a facility for large scale storage of alternatives water sources. The best approaches for aquifer recharge, which include water quantity and quality monitoring and purification by natural attenuation and filtration processes from soil aquifer treatment (SAT), are the focus of the following PT DEMO sites (Fig. 1):

- PT1: Rio Seco and Campina de Faro aquifer system (Algarve), with 3 subsites.
- PT2: Querença-Silves limestone karstic aquifer system (Algarve), with two subsites.
- PT3: Melides aquifer, river and lagoon (Alentejo). This site is not detailed in this abstract.

2. MARSOL DEMO SITES CHARACTERISATION IN PORTUGAL

2.1. PT1: Rio Seco and Campina de Faro aquifer system (Algarve)

Site description and objective

PT1 aims to demonstrate that the aquifer water quality can be improved by means of MAR. For this purpose, infiltration basins constructed in the Rio Seco river bed are being tested and monitored, using either the basins constructed in 2006 during GABARDINE EU project (PT1_1), which were rehabilitated during MARSOL, or

the new MARSOL basins (PT1_2) constructed in July/August 2014. Furthermore, infiltration in typical existing large-diameter wells (PT1_3) is being tested as a potential MAR facility to increase the water recharge at a regional scale and improve the groundwater quality status, using the water collected in the greenhouses roofs during rain events.

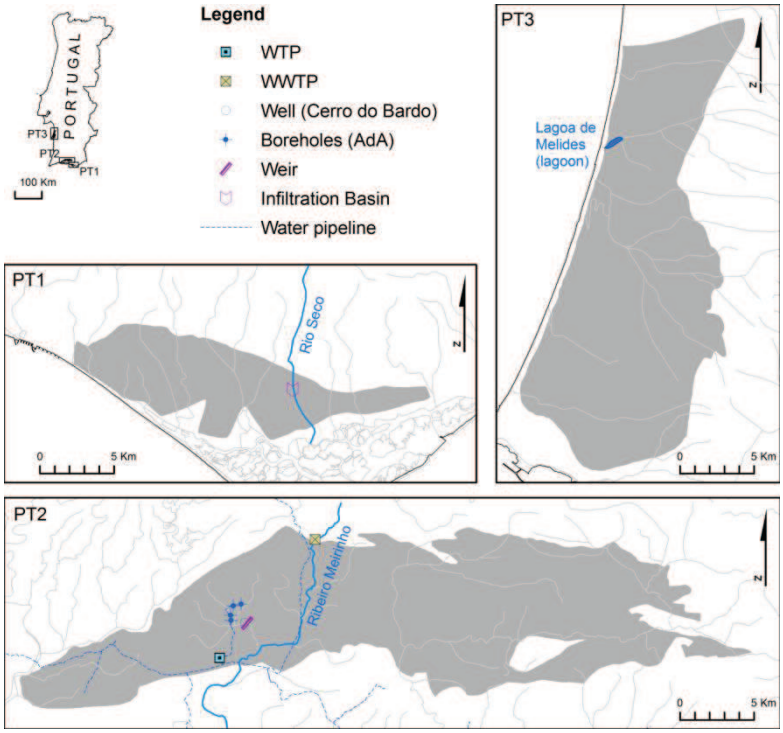

Fig. 1. Location of the PT MARSOL DEMO sites (Leitão *et al*., 2015)

The rehabilitation of the structures inherited from the GABARDINE EU project (2005-09) in Rio Seco - Campina de Faro took place between 25th and 26th July 2014. They consist of two infiltration basins - with approximately 20 m long, 5 m wide and 6 m deep.

The constructed MARSOL basin has an average depth of 6.7 m, a total length of 33 m and occupies the entire cross section of the river, with an average width of 6.1 m at the surface (cross-section of the river varying between 5.5 to 6.2 m). This basin has a surface area of 201 m^2 (33 m x 6.1 m). Vertically it presents a perfectly rectangular configuration (vertical slopes) across its lateral extent (Fig. 2).

Several piezometers and wells were installed (Fig. 3). These infrastructures aim to control and monitor the injection tests performed at Rio Seco, in both MARSOL's and GABARDINE´s infiltration basins (dug in the upper aquifer), and to improve the geological knowledge of the MARSOL basin area.

River basin excavation: August 2014 River basin filling: August 2014

Fig. 2. Construction of a new MARSOL infiltration basin and new monitoring piezometers at PT1_2 Campina de Faro (Leitão *et al*., 2015)

The MARSOL piezometers reached depths between 20 and 30 m, and mostly crossed the Upper Miocene

formations (clay and sand), superficially covered by more or less consolidated gravel.

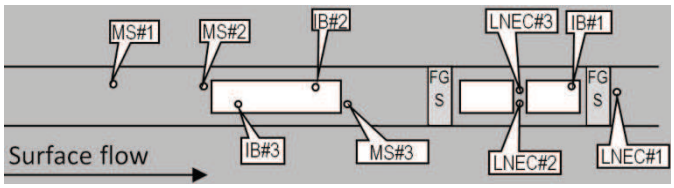

Fig. 3. Location of the piezometers and all infrastructures at Rio Seco (Leitão *et al*., 2015)

Field experiments conducted

Upon the completion of the infiltration basins work, several tests were performed in order to evaluate the performance of the basins in terms of clogging, infiltration rates and its local influence in the groundwater quality. Besides, a test was conducted in a large diameter well to assess its infiltration rate capacity.

The following tests were performed:

- PT1_1: Clogging test in one GABARDINE basin, 1st July, 2014
- PT1_1 and PT1_2: Infiltration test in all three basins, 29-30th September, 2014
- PT1_2: Tracer test in MARSOL basin, 13-14th October, 2014
- PT1_3: Infiltration in large wells, 1st October, 2014

Oliveira *et al*. (2015) present the results of the clogging test conducted on 1st July, 2014.

2.2. PT2: Querença-Silves limestone karstic aquifer system (Algarve)

Site description and objective

PT2, Querença-Silves limestone karst aquifer system (Algarve) DEMO site aims to: (1) develop a SAT system to improve the water quality of treated effluents from a WWTP (PT2_4), which discharges water into Ribeiro Meirinho river (PT2_5) and (2) increase groundwater storage using MAR to recharge surplus of surface water during wet years at Cerro do Bardo well (PT2_6), located next to a tributary of Ribeiro Meirinho. This will contribute to increase the water availability in dry years, facilitating downstream water supply pumping.

During 2014, the work developed in PT2_4 consisted in the characterization of the treated wastewater effluent in several different occasions (Fig. 4), as well as the development of several soil-column tests in LNEC laboratory facilities (Fig. 5) to determine the pollutants removal capacity of local soils. Martins *et al*. (2015) present the results of the performed soil-column tests.

Fig. 4. Sampling the WWTP for water collection at SB Messines

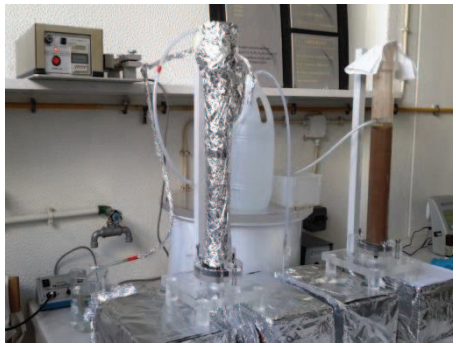

Fig. 5. LNEC soil-column experimental setup

The work developed in PT2_6 Cerro do Bardo site (Fig. 6) consisted in the rehabilitation of an existing small dam at Aivados and the private owned Cerro do Bardo well. This work took place between November 10th and 19th 2014. The location of the construction work is Barranco de Aivados, located close to Cerro do Bardo, at approximately 4 km NW of Algoz, specifically in the parish of Alcantarilha / Silves.

The objective of Cerro do Bardo Site is to investigate and conceptualize the possibility of enhancing the regional water management by using surface water and MAR Techniques to increase groundwater availability, possibly enhancing water supply wells productivity.

Fig. 6. Cerro do Bardo well and Aivados dam (PT2_6) (Leitão *et al*., 2015)

Field experiments conducted

The preferred water flow direction of the infiltrated water in the aquifer was assessed through an injection and tracer test done in April and December 2014, respectively. Preliminary results of tests in the Cerro do Bardo (PT2_6) large diameter well suggest adequate conditions for installation of a MAR site, considering the large diameter well is characterized by high infiltration rates.

The following tests were performed:

- PT2_4: Assessment of WWTP quality, May and September, 2014
- PT2_6: Quantitative infiltration test, 1st April, 2014
- PT2_6: Quantitative infiltration test, 15-19th December, 2014

Costa *et al*. (2015) present the interpretation of an injection test in a large diameter well conducted on 1st April.

3. FINAL REMARKS

This paper presents a short overview of MARSOL project, its main objectives, as well as the work being developed in Portugal. Several experiments have been and are being conducted, and will be presented separately. Their dimension and interest is not possible to resume here, so the aim of the paper is solely to highlight some features and the main aims of the on-going work.

In PT1 Rio Seco and Campina de Faro aquifer system (Algarve), injection and tracer tests have been done to determine basins infiltration rates, and velocity and dispersion in the aquifer. In that demo site, a continuous monitoring of all system is now in place to assess the effect of all precipitation episodes and their influence in the infiltration basins and the aquifer.

In PT2 Querença-Silves limestone karstic aquifer system (Algarve), injection and tracer tests have been done to determine a large well's infiltration capacity and the main groundwater flow direction. Besides, several soil-column experiments were performed to determine, at lab scale, infiltration rates and soil removal capacity for some nutrients, toxic metals, metalloids and pharmaceutical originated from wastewater, and prior to MAR.

ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no 619120 (Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought – MARSOL). We also thank Agência Portuguesa do Ambiente (APA-ARH Algarve) and Águas do Algarve (AdA) for all their support during this project.

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