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CONGRESSO
DA ÁGUA

ESTIMATING THE EFFECT OF GREENHOUSE-HARVESTED RAINWATER TO REMEDIATE NITRATE CONTAMINATED GROUNDWATER IN SOUTH PORTUGAL

Luis COSTA[1], José Paulo MONTEIRO[2], Rui HUGMAN[3], Kathleen STANDEN[4]

1. *Centro de Ciência e Tecnocoloa / Universidade do Algarve, Faro, Portugal, luisrdcosta@gmail.com*
2. *Centro de Ciência e Tecnocoloa / Universidade do Algarve, Faro, Portugal, jpmontei@ualg.pt*
3. *Umvoto Africa (Pty) Ltd, Cape Town, South Africa, rthugman@gmail.com*
4. *Centro de Ciência e Tecnocoloa / Universidade do Algarve, Faro, Portugal, kestanden@ualg.pt*

RESUMO

Nitrate concentrations reach values as high as 300 mg/l in the Campina de Faro aquifer despite being included within a Nitrate Vulnerable Zone. In order to reach “Good groundwater status” according to the EU Water Framework Directive, further measures need to be implemented. Managed Aquifer Recharge by injection of rainwater into pre-existing traditional large dug wells, is proposed as a possible measure. Water availability for infiltration was estimated from the potential rainwater that can be harvested at greenhouses’ rooftop. Traditional dug wells were inventoried and their infiltration capacity assessed by injection tests, which suggested good infiltration capacity and potential infrastructure for MAR. In the most critical area, there is a potential Water availability of 1.50 hm3/year that could be injected in existing wells, which represents approximately 10% of the aquifer water balance. The effect of injecting this volume in the aquifer was estimated with the support of a 3D numerical groundwater flow and transport model. Results of which show there is a slight improvement in the majority of observation points, with a reduction of nitrate violations from, 33 to 30 by 2027, although the most important result consists in the observed large decrease of nitrate concentration in the most affected areas, as long as there are infiltration wells. Notwithstanding, issues like clogging, conditions of greenhouses and wells and water quality have to be taken into consideration for these factors can negatively impact the efficiency of the solution.

Palavras-Chave: Managed Aquifer Recharge; Groundwater numerical modelling; direct infiltration; nitrate contamination; rainwater harvesting

1. INTRODUCTION

Groundwater contaminaion in south Portugal Nitrate Vulnerable Zone (NVZ) of Faro can reach values as high as 300 mg/l, mostly on the Campina de Faro aquifer, due to intensive agricultural practices in the past (Stigter et al. 2013). According to the Water Framework Directive (WFD) measures should be implemented in order to contribute to improve groundwater chemical status of every groundwater body by 2027, which, in the case of nitrates in groundwater corresponds to a threshold value of 50 mg/l. In the present work, a Managed Aquifer Recharge scheme is proposed as a measure to contribute to the remediation of the nitrate problem on the NVZ Faro. The eventual MAR scheme focus on a low cost solutions, by harvesting rainwater from greenhouses and use exhisting dug wells as a direct infiltration infrastructure. Results of such scheme are estimated wity the implementaions of a groundwater and mass transport numerical model.

2. CASE STUDY

The study area consists of the set of aquifers included in the Nitrate Vulnerable Zone of Faro (NVZ-Faro), Algarve, the southernmost province of Portugal as indicated in **Erro! A origem da referência não foi encontrada.**. These aquifers are Almansil - Medronhal (M9), São João da Venda – Quelfes (M10), Chão de Cevada – Quinta João de Ourém (M11) and Campina de Faro (M12) and in total, the NVZ occupies na área of 97.73km^2. Nitrate concentrations in the arae became a major concern in the 80’s, reaching values as high as 300

– 400 mg/l, and to the definition of the Nitrate Vulnerable Zone (NVZ). Monitoring of nitrates in the NVZ provide evidence that a well-defined nitrate contaminant plume is slowly heading towards the Ria Formosa coastal lagoon, with evidence of decreasing values of nitrates in the northernmost region and increasing values towards the south (Leitão et al. 2015; Stigter 2005; Stigter et al. 2013). During FP7 MARSOL project (FP7/2007-2013 GA619120) new nitrates sampling campaigns around the city of Faro were performed in order to assess the evolution of the nitrate contamination between 2014 and 2016, results of which, together with the results of the official monitoring network of the regulatory water agency (Agência Portuguesa do Ambiente - APA) show there is no significant improvement of the nitrate contamination plume (Fig. 1).

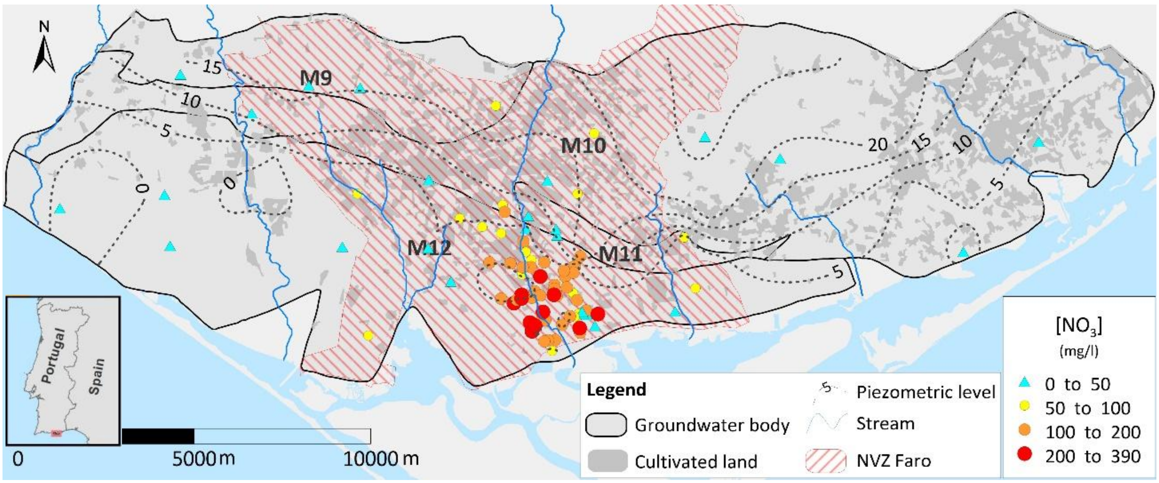

Fig. 1 – Location of case study aquifers and Observed Nitrate concentration and piezometric levels from May 2016 according to observation points from Environmental Protection Agency and MARSOL sampling campaigns.

3. METHODOLOGYCONCLUSÕES

The MAR scheme presented foccus on rainwater harvesting at greenouses for latter infiltraiton in dug exhiting wells. Water availability was estimated from geographic distribution of average annual and monthly rainfall (calculated from Nicolau, 2002) and its interception with exhiting greehouses in the case study area, estimated from satellite view Later, exhisting dug wells were inventoried and 1 was selected to perform an infiltration test in order to assess the infiltration capacity of these infrastructures. Wells were selected according to a 150 m distance buffer from the greenhouses. Finnally, the effect of the MAR scheme on groundwater nitrate concentration was estimated with tue support of a numerical groundwater a mass transport model, using finite element code FEFLOW (Diersch 2014). The model originally developed by Hugman et al., (2017) was adapted to be composed by three layers, 715,107 triangular prism elements and 483,688 nodes. Constant head boundary conditions (BC) equal to 0 were imposed along the coast to simulate groundwater discharge. Temporary streams were assigned constant head BC equal to surface elevation, but constrained to only allow flow out of the model. Well BC were assigned to nodes corresponding to golf courses irrigated with groundwater and within cultivated irrigated areas, with abstraction rates calculated according to water demand and irrigation efficiency for each specific plot of agricultural land.

Nitrate input was distributed according to cultivated landuse identified in Carta de Ocupação de Solos 2010. The value was estimated based on nitrate reference values defined by the River Basin Management Plan and imposed within the NVZ limits at the top slice of the model as point sources mass-transport BC. Of the total area, 81.24 km^2 (83%) are used for agriculture or are occupied by forests (Rosário Carvalho, 2019).

Two modellign scenarios were defined, the Business as Usual (BAU), and the scenario with the injection of harvested rainwater in wells (INJ), both simulated from 2016 until 2040 and results were compared.

4. RESULTS AND CONCLUSIONS

Rainfall estimates at M12 indicate an annual average of 570 mm with the spatial distribution shown in Fig. 6. The location of the greenhouses and their surfaces was obtained from the land use survey provided from APA-ARH Algarve I.P. Only the greenhouses which are totally within or intercept the CF limits were considered in this study and their total surface area account for 2.74 km2 with spatial distribution as seen in Fig. 2. The intercpetion of thse values corresponds to 1.63 hm^3/year, although, considering only the greenhouses within the 150 m distance buffer to the dug wells, this value decreases to 1.50hm^3/year.

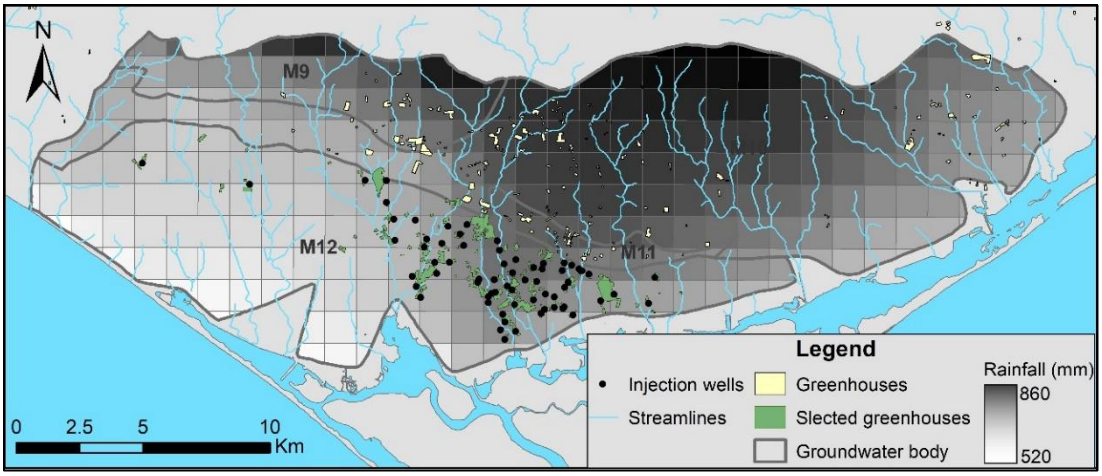

Fig. 2 – Average annual rainfall spatial distribution on M12 aquifer (based on Nicolau (2002)) and greenhouse location (based on APA-ARH Algarve, unpublished) and selected injection wells.

Infiltration capacity of the dug wells were shown to have enough infiltration capacity to accomodate the generated water source for MAR yearly (Costa et al. 2015).

Simulated results of nitrate concentration were compared for both scenarios, BAU and INJ, based on monitoring points available (Fig. 1).

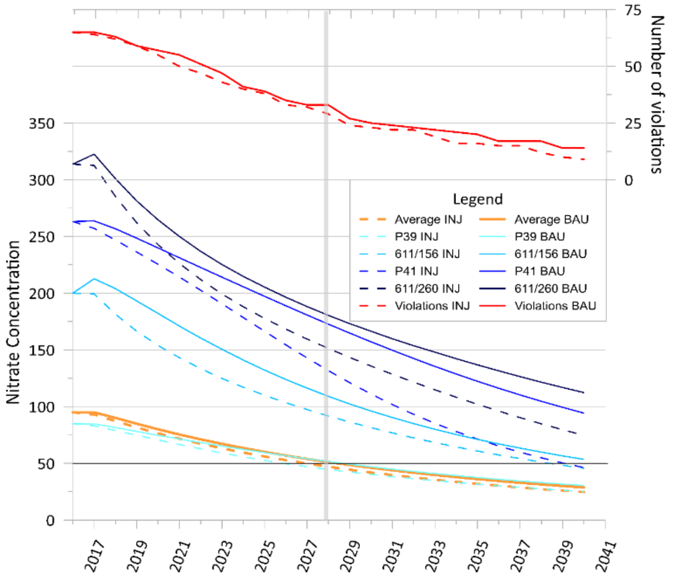

Fig. 3 – Left Axis: simulated evolution of groundwater nitrate concentration for both scenarios at four monitoring points (P39, P41, 611/156 and 611/260) and annual average of all 91 quality monitoring points. Right Axis: simulated evolution of the number of violation of groundwater nitrate concentration.

Both scenarios were simulated from 2016 to 2040. In general, model results for 2027, i.e., the end of the 3rd river basin management cycle plan according to the WFD, show that for BAU, there will be 33 observation points with concentration higher than 50 mg/l of which, 10 belong to violations of the official monitoring network (Fig. 8). As for INJ scenario, the number of violations by 2027 is 30, of which 9 belong to the official network. Considering the final step of the simulation, i.e. 2040, model results show 9 violations for the INJ scenario and 14 violations for the BAU scenario, of which, 2 and 3 respectively belong to the official network for each scenario. Although the decrease of of violations for INJ scenario is not considerable it is importante to mention that this scenarios benefits from the large decrease in high concentration zones, since this is where the model shows the effect of the proposed MAR scheme to be more efficient (see for example observation points 611/260 and P41 from Fig. 3).

It can be concluded that the presented MAR scheme may not have an considerable impact in the recuction of the number of violations, but may induce a significant decrease in nitrate concentration in particular in the areas with high concentration nitrate.

AKNOWLEDGEMENTS

Research leading to these results would like to aknowledge support from FP7 project (FP7/2007-2013 GA619120 (MARSOL), Agência Portuguesa do Ambiente and Luís Costa would like to aknowledge Fundação para a Ciência e Tecnologia for the PhD grant SFRH/BD/131568/2017.

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