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LIVRO DE RESUMOS

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10.º SEMINÁRIO SOBRE ÁGUAS SUBTERRÂNEAS

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LIVRO DE RESUMOS do 10.º Seminário sobre Águas Subterrâneas

ASSESSMENT OF SOIL CHARACTERISTICS FOR MANAGED AQUIFER RECHARGE USING SOIL-COLUMN EXPERIMENTS

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ABSTRACT

Managed Aquifer Recharge (MAR) main purpose is to augment the water availability in aquifers during times of excess to help addressing water scarcity challenges. Besides, these systems can have the goal of improving the quality of the recharged water. One of the main existing challenges of MAR is to control the infiltration rates and avoid clogging due to physical, chemical and biological processes taking place during the transport of water through the unsaturated and saturated zone. Soil-column experiments are frequently used to get information on the soil behaviour under controlled conditions.

In the framework of EU MARSOL project, several soil-column experiments were conducted at LNEC using a soil collected in SB Messines, one of the Algarve demo sites. This paper presents the first results concerning the soil flow rate variations under different conditions, aiming at verifying the soil suitability for infiltration media in basins. The soil capacity for sorption and biodegradation of the pollutants from a wastewater treatment plant (WWTP) are also being tested, but the results are not yet available.

Key-words: MAR (Managed Aquifer Recharge); soil-column experiments; SAT (soil-aquifer treatment); flow rate; velocity; permeability.

1. INTRODUCTION

In one of the three Portuguese demo sites of MARSOL project (Leitão et al., 2015), PT2_4 – WWTP SB Messines, a soil-aquifer treatment (SAT) system will be built during 2015, using infiltration basins as treatment media to improve water quality, prior to recharge. For that purpose, several soil-column laboratory experiments were planned aiming to choose the most adequate soil layer for the basin fill, taking into consideration the soil permeability and also its capacity for retaining some specific pollutants from the inflow water like nutrients and pharmaceuticals, which increasing concentrations in the environment can be a significant problem.

A set of soil-column experiments was defined and conducted between May 2014 and March 2015 at LNEC to determine the hydraulic characteristics of the local soil. These experiments used as inflow either deionized water and/or wastewater from SB Messines WWTP. The main objective of these tests is to determine the soil infiltration capacity as well as its capacity to retain the wastewater contaminants after secondary treatment, and therefore evaluate the potential for using them in SAT infiltration basins. The latter are also highly dependent on the soil permeability variations since they control the water residence time, and therefore the chemical and biological equilibrium during the infiltration process. Artificial or commercial soils may also be considered at a later stage depending on the results of soil-column experiments.

The results of 5 soil-column experiments concerning the flow rate variations encountered resulting to the different assembling methods are presented. Uncertainty factors are also briefly discussed.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Soil-column apparatus

The soil-column experimental apparatus used consists of a PEAD transparent column with 30 cm height and 5 cm diameter (Fig. 1), used for the soil-column experiments 1, 2 and 3. In soil-column experiments 3 and 4 the PEAD column was 50 cm high with a similar diameter allowing the existence of a controlled height of water on the top of the soil, simulating the conditions of real scale infiltration basins. In all experiments the soil used had the same volume, corresponding to 30 cm height and 5 cm diameter, except for column 3 where the height was 20 cm. The soil-column was attached to a compaction system composed of a standardized weight disk for soil compaction and a ruler for dropping height determination. All columns have a tight lid base with an outlet port which is connected to a sample tube where the outflow water is collected. An inert Teflon membrane filter is added to the soil-column bottom for fine particles retention.

For continuous water injection, a volumetric peristaltic pump was used. For pulse injection, the water was directly poured from a container to the column. Outflow samples were collected at defined periods.

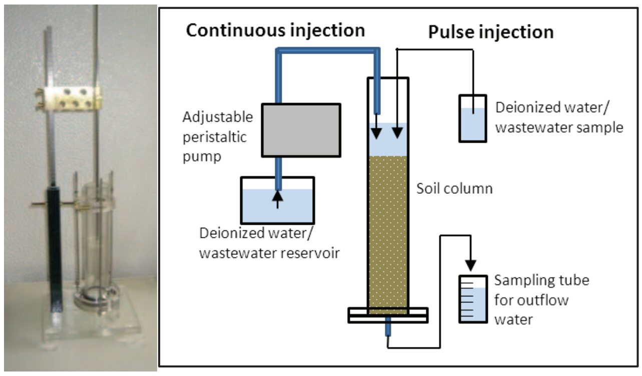

Fig. 1. Soil-column apparatus and diagram of operation

2.1.2. Soil preparation

Soil samples were collected at the approximate location of the infiltration site in the outskirts of SB Messines wastewater treatment plant, removing the most superficial layer, and collecting soil from a depth of 5 to 20 cm. The soil was dried at 40°C, the large organic matter (roots, leaves, etc.) was manually removed; afterwards it was quartered and split in equal portions to be representative of the site soil. In addition to the soil-column experiments, soil granulometry, organic matter percentage, carbonate percentage, cation-exchange capacity and clay type were also determined.

For the experiments 2 to 4 the soil, which has the tendency to form clay aggregates, was disaggregated in a mortar and then sieved, having the particles larger than 2 mm excluded from the column filling sample (93% of SBM soil particles are below 2 mm size).

2.2. Methods

After the column assembling and the Teflon filter correctly positioned at the bottom end section, the soil-column was filled following the CEN/Technical Specification 14405 (2004): fill the column in 5 cm soil sections packing each section with the weight, dropping it three times over a 20 cm height above it. In this process the whole surface should be covered with the weight disk after three drops for maximum regularization. The surface was then scarified before addition of another 5 cm layer. The process was repeated 5 times until the column was completely filled. The soil column was then weighted. This compaction method was applied to all soil-column experiment except column 5, where the number of weight drops was reduced to two instead of three.

In the top section of columns 4 and 5 a non-reactive permeable layer was used to assure an equal distribution of the input water and minimum disturbance of the first layer of soil during the water injection, also preventing an early clogging process. This layer was composed of Fontainebleu quartz white sand with an approximate thickness of 0.5 cm.

For all 5 soil-column experiments the soil was completely saturated with deionized water from bottom to top for about 16 hours allowing the reduction of air-pockets inside the soil which may have resulted in preferential flow paths for water – Fig. 2. All columns except column 5 started with continuous flow from the top using an automatic peristaltic pump. Column 5 started with pulse injection of approximately 378 ml of deionized water, filling the 20 cm top of the column.

Following Gibert et al. (2015), the transparent parts of the setup were wrapped in aluminium foil to simulate non-light conditions encountered in the subsurface, and to reduce photolithotrophic microorganisms growth of and photodegradation of contaminants.

The experiments were held in different time periods, from a few hours (column 2) to several days (column 3, 4 and 5). For columns 4 and 5 an unsaturation period was considered after every injection period in order to recreate the field conditions for contaminant degradation enhancement through oxygenation process.

The details concerning the 5 soil-column experiments are summarized in Tab. 1. The different experiments aimed to assess the importance that compaction procedures, saturation-desaturation and infiltration water quality can have in the flow rate of the same soil, also for different time periods.

Fig. 2. Bottom to top soil saturation (Column 1)

Tab. 1. Soil-column experiments assembling and procedure details

	Column 1	Column 2	Column 3	Column 4	Column 5
Column height (cm)	30	30	30	50	50
Soil thickness (cm)	30	30	20	30	30
Sieved	No	Yes	Yes	Yes	Yes
Soil packing	Specific weight - 3 strikes	Specific weight - 3 strikes	Specific weight - 3 strikes	Specific weight - 3 strikes	Specific weight - 2 strikes
Saturation conditions	Started saturated Always saturated	Started saturated Always saturated;	Started saturated Always saturated	Started saturated Unsaturated/saturated cycles	Started saturated Unsaturated/saturated cycles
Injection	Continuous	Continuous	Continuous	Continuous/pulse	Pulse
Inert sand layer on soil top	No	No	No	Yes (0.5 cm)	Yes (0.5 cm)
Water matrix	Deionized	Deionized	Deionized/Wastewater	Wastewater	Deionized/Wastewater
Experiment time (days)	0.97 (finished)	0.11 (finished)	4.25 (finished)	17.91 (not finished)	4.46 (not finished)

3. RESULTS AND CONCLUSIONS

The main results are summarized in Tab. 2. Porosity and density present similar values for the 5 columns, although different assembling methods were used. This is also valid for the pore volume values are similar (considering that the pore volume for column 3, with 20 cm, is 173.2 ml × 3/2 is 259.8 ml). The main differences are observed in the flow rates and therefore velocity values. As can be observed in Fig. 3 flow rate tends to naturally decrease over time, mainly in the first 100 minutes. After this period the flow rate continues to decrease but not as fast. Although Fig. 3 only shows flow rates for a period of 600 minutes it was observed that flow rate and velocity keep decreasing over time. The lower flow rates were observed for column 4 (0,01 cm^3/min) at the 4th cycle of saturation/unsaturation. However, at every injection pulse, the flow rate temporarily increases, certainly due to the increase of the water hydraulic gradient above the soil top.

Tab. 2. Results from soil-column experiments

		Column 1	Column 2	Column 3	Column 4	Column 5
Porosity (%)		45.9	43.1	44.1	43.4	41.8
Density (g/cm^3)		1.4	1.4	1.4	1.5	1.5
Pore volume (ml)		270.1	253.5	173.2	261.1	256.3
Flow rate (cm^3/min)	**Day 1**	0.85	1.48	0.87	0.36	1.41
	Experiment time	0.85	1.48	0.79	0.36	0.81
Permeability (Darcy) (m/d)	**Day 1**	1.36	2.52	1.45	0.59	2.64
	Experiment time	1.35	2.52	1.31	0.58	1.37

Comparing all experiments, column 4 is the one that shows lower flow rate and velocity values. This may result from the fact that injection started with wastewater and not with deionized water. Wastewater itself is more dense then deionized water and has considerable organic and biological loads, therefore increasing the possibility for clogging. Column 5 was tested with wastewater as well but due to the lower compaction presented a hydraulic performance more suitable for the purposes of SAT-MAR.

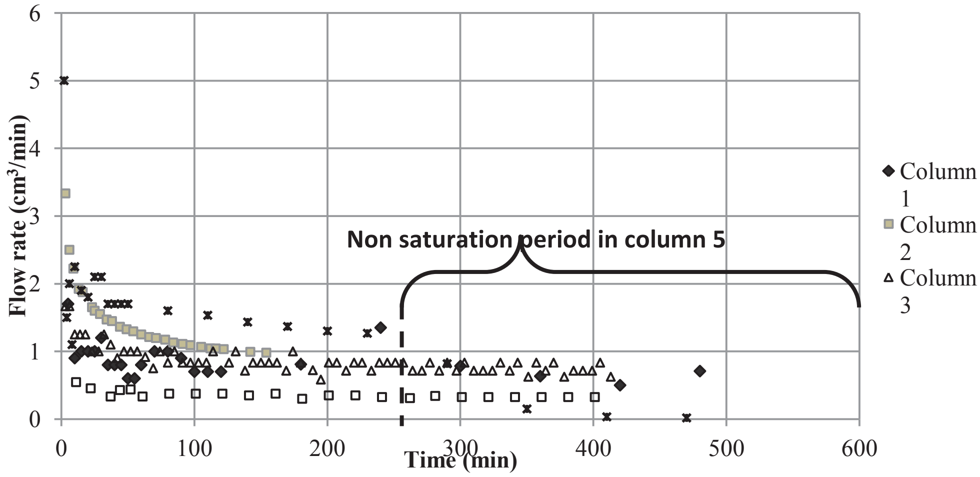

Fig. 3. Time (min) *versus* flow rate (cm^3/min) for the initial days of the soil-column experiments

In synthesis, these experiments allowed gathering of information on the long term behaviour, at laboratory scale, of SB Messines soil, providing the first basis for decision regarding its the suitability for MAR processes.

As conclusion, the soil collected in the outskirts of the SB Messines WWTP shows some suitability to be used as a base infiltration layer for the SAT-MAR infiltration basins, in what concerns the infiltration capacity.

Based on the range of laboratory flow rates obtained, in the two basins programed to be constructed (each one with 15x7 m), the wastewater volume that could be infiltrated ranges from 6 - 25 % of the total SB Messines WWTP outflow volume (approx. 900 m^3/d).

In the near future an improved layer using this soil (e.g. mixed with a more pervious material) will be tested in soil column experiments, aiming at obtaining higher infiltration rates as well as the necessary retention time for contaminants reduction. Further information about contaminant retention capacity is being collected.

It should be noted that the definition of column assembly and construction methods is an iterative process where the objective is to simplify the reality to the laboratory scale. At the same time, the maximum number of uncertainty factors that can compromise the results have to be eliminated so the soil-column experiment can be as close as possible to reality making easily understandable the processes that take place inside de soil-column.

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BIBLIOGRAPHY

Gibert O, Hernandéz M, Vilanova E, Cornellà O (2015) Guidelining protocol for column experiments assessing fate and transport of trace organics - research project DEMEAU, 50 pp.

Leitão TE, Lobo Ferreira JP, Oliveira MM, Martins T, Henriques MJ, Carvalho TM, Martins de Carvalho J, Agostinho R, Monteiro JP, Costa LRD (2015) Deliverable 4.2 South Portugal MARSOL Demonstration Sites Characterisation. EU MARSOL Projet - Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought, 78 pp.

Kübeck C, Silver M, Wefer-Roehl A, Leitão TE, Martins T, Henriques MJ, Kurtzman D (2014) Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought Interim Report for the Project Period December 2013 – August 2014, 14 pp.

CEN/TS14405:2004 Technical Specification – Characterization of waste – Leaching behaviour tests – Up-flow percolation test (under specified conditions), European Committee for Standardization (2004) 25 pp.