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Abstract: This study aims to enlighten the geometric changes at the pore scale of filtering media of Vertical Flow Treatment Wetlands (VFTW) and their influence on oxygenation during the rest period. A 3-day ex-situ drying of six samples of a VFTW was carried out at controlled temperature, and relative humidity simulating the rest period. Samples (16-cm long) were taken at the end of the feeding period of a filter in the first stage and let dry. Three of the samples were sterilized before drying using gamma rays to differentiate oxygenation without bacterial activity. At 0, 1 and 3 days of drying, X-ray scans of the samples were performed to observe changes in the samples structure. After each scan, the oxygen transport within the sample was studied by measuring vertical oxygen concentration profiles. Although X-ray tomography allows small structure changes to be detected, it is necessary to modify the drying conditions perform a more realistic drying. The complexity of the results of oxygen profiles lead us to suggest the use of CFD tools to understand how oxygenation occurs.

Key words: Treatment Wetlands, X-ray Computed Tomography, Pore Structure, Oxygen Transfer

Session: Operation and maintenance: clogging, vegetation managemen

Introduction

X-ray tomography is a technique frequently applied to study pore media at the pore scale. It has been proven to produce good quality images of VFTW filtering media and it is well adapted to record changes in pore structure due to drying operations. (Martinez Carvajal et al. 2017)

First stage filters in French VFTW are fed with raw waste water for 3.5 days and let rest for the 7 consecutive days (Molle et al. 2005). The respect of this cycle is necessary to maintain aerobic conditions in the filters (thanks to deposit dewatering, and evapotranspiration), let mineralization to take place and control biomass growth. Dewatering and evapotranspiration are probably the major responsible of changes in deposit and voids structure allowing faster water infiltration. The objective of this study is to contribute to a better knowledge of processes occurring during the rest period by performing an ex-situ drying of the filtering medium and following it by X-ray tomography.

Material and methods

Six samples were extracted manually at the end of the feeding period of one filter of the first stage of the treatment plant in Montromant (France) in summer. This plant was built in 1994 to treat 200 people equivalent according to the French standards (Molle et al. 2005).

Three sampling points with similar electric conductivity were chosen based on an EM mapping. The samples consisted of plastic cylinders 5cm diameter and 16cm height containing the first part of the filtration layer. Two samples per point were extracted. Three samples, one per sampling point ("Blabeled”), were sterilized with a dose of 31.8 kGr of gamma rays to suppress bacterial activity. All samples were stored at 5°C in before starting the drying operation.

The drying operation was held in an acrylic glass chamber covered with a polystyrene jacket for 72 hours. The temperature was maintained at 25°C.The relative humidity was maintaned near the equilibrium value of 75% using a 2 liter NaCl saturated solution. During the drying operation only the top of the cylinder was left in contact with the chamber’s atmosphere.

Samples were scanned by X-ray tomography at 0, 24 and 72 hours of drying. The resolution was 35µm/voxel. After each scan, six oxygen probes were inserted 0.5 cm into the samples and placed every 2.5 cm from the top. The probes were calibrated into a 0-100% scale. A N_2(g) flow of 1 m/s (D = 5mm) was fed through the bottom of the sample for at least ten minutes. After the N_2(g) flow was stopped the samples were allowed to be oxygenated naturally with the air inside the chamber and the oxygen concentration profile was recorded for at least 40 min.

Results and discussion

The scans in Figure 1 show the structure of one of the samples. There are three main gray levels: (i) black for voids, (ii) light gray/white for gravels and (iii) middle gray, which represent plant tissues, remaining water and filtrated solids (mostly organic). For simplicity, the middle gray will be called OM (organic matter). The topmost 9 cm of the sample consist mainly of OM while the rest is a mix of gravel and OM (Figure 1a). The scans do not show significant changes in the voids structure over the drying period. Based on previous observations of deposit cracks formed during the rest period it seems reasonable to state that drying was not representative.

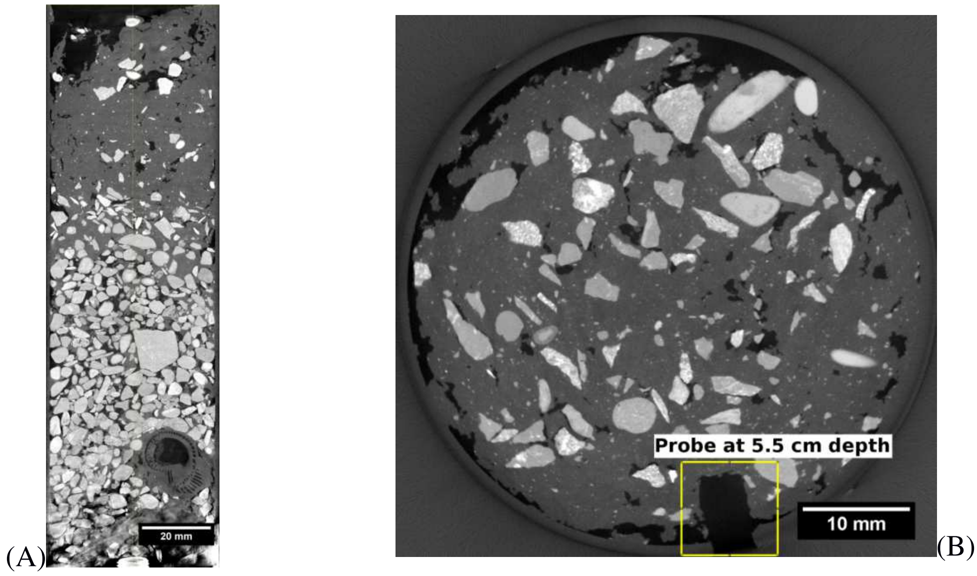

Figure 1. Slices of a X-ray scan of a sample of filterig medium. (A): Vertical slice at 0h of drying. (B). Horizontal slice at depth = 5.5 cm

The water loss during the drying period is presented in Table 1. All of the samples had similar losses around 2.5%(v/v) and the only force inducing it was evaporation (no evapotranspiration is possible at the sample's size).

The methodology presented in this work should be modified to perform an ex-situ drying as similar as possible as in real outdoor conditions. The key parameter to reproduce is probably the amount of water evaporation.

Table 1. Water loss during after 72h of drying (ex-situ)

Sample	1A	2A	3A	1B	2B	3B
Total mass loss (g)	8.47	8.13	9.05	6.37	5.84	9.4
Volume Loss : V_{water}/V_{sample}	2.70%	2.59%	2.88	2.03	1.86	2.99

Diffusion should be the main mechanism of vapor and oxygen transport during the drying as there was no induced air movement inside the chamber. This may be verified by comparing measurements of oxygen concentration and CFD simulations of oxygenation.

The oxygen profiles for samples 1A and 1B, are presented in Figure 2. One should expect that (i) profiles are sorted depending on the probe depths and that (ii) oxygen concentrations are higher in the sterilized sample as bacterial activity was suppressed. Neither of these behaviors is depicted in Figure 2.

(1A) (1B)

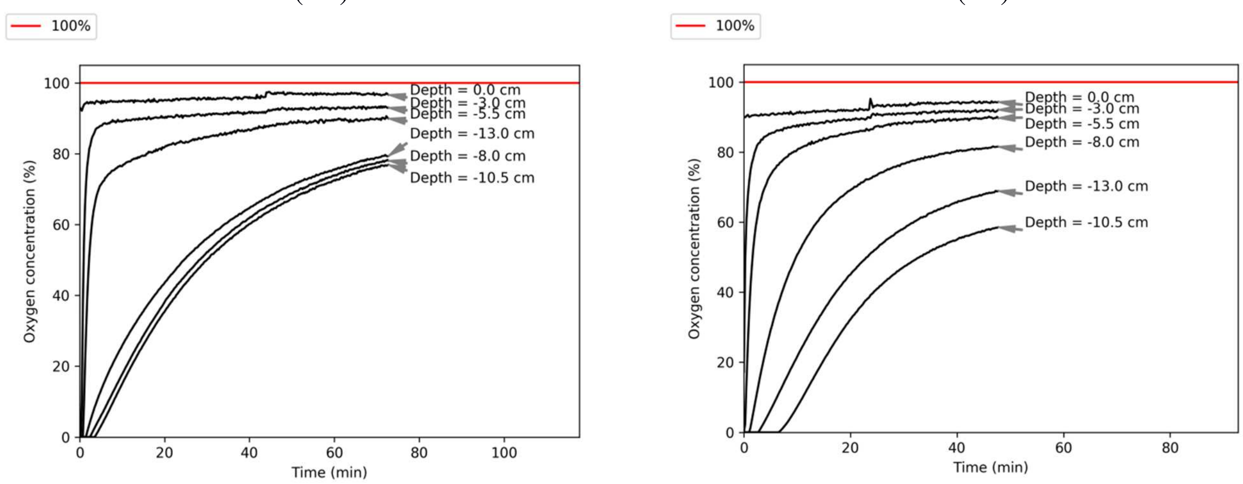

Figure 2. Oxygen profiles evolution for two samples after 72h drying.

Left: sample 1A (No sterilized sample). Righ: sample 1B (Sterilized sample)

The difficulties to design a proper experimental methodology and the high number of phenomena taking place at the same time make CFD simulations an interesting way to understand soluble solute transport in wetlands filtering media. For instance, the voids structure around the probes (Figure 1B) could explain the oxygenation results in Figure 2.

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