Enhanced removal of urban stormwater runoff contaminants using biochar and manganese oxide-coated sand geomedia in a sequential biofiltration system

Samantha Burnell[1], Dr. Marc Teixido Planes[2], Prof. David Sedlak[2]

[1]MIT, Department of Civil and Environmental Engineering

[2]UC Berkeley, Department of Civil and Environmental Engineering

Introduction

When storms occur in urban areas, water doesn't percolate into the ground as easily as in nonurban areas, because of all the impervious material on the ground such as asphalt. This causes the stormwater to run through the streets, collecting pollutants along the way, before finally discharging into surface water. Additionally, stormwater is increasingly being seen as a potential local source of water in water scarce urban areas of the West. If properly treated, stormwater could be a valuable source of drinking water. The City of Los Angeles plans to install novel stormwater capture, treatment and recharge (CTR) systems to augment local drinking water supplies (e.g., Rory M. Shaw Wetlands Park). Stormwater will be collected in a detention pond, sent through a wetland, percolated through a passive filtration system, and finally used to recharge an aquifer.[1] The aim of this study is to evaluate and optimize the removal of trace organic contaminants (TrOCs) in the passive infiltration systems prior to groundwater recharge. Recent studies have shown that redox conditions and levels of biodegradable organic carbon (BDOC) can have a significant effect on the removal of TrOCs.[2] In addition, removal of BDOC is a measure of filter performance, improves the biological stability of the effluent and minimizes problems (e.g., metal mobilization) during recharge. For the reasons listed above, in this study BDOC was chosen as a metric of the column system's removal efficacy.

Materials and Methods

Field site and Materials Description

The field site is located at Ken Malloy Harbor Park in Wilmington, California. The columns used in this study are 1-meter length and 2 inches internal diameter. The columns with different configurations were filled with sand, biochar (0.5 wt.%), MnOx-coated sand, or a combination of MnOx-coated sand and biochar (0.5 wt.%) (Figure 1, B). Captured stormwater from the detention pond and wetland effluent are pumped to a sequential column system. First, through a column, followed by an aeration flask (intended to return oxygen to the water to re-stablish oxic conditions), and a second column. The studied columns were built and deployed in the field prior to summer 2019.

BDOC Testing and SUVA Calculation

Samples were taken from the column effluents. 200 mL were filtered at 0.2 µm GF (Glass Fiber), pre-flushed with Milli-Q water, to remove microorganisms and particulates. A 2-mL inoculum (from the unfiltered remaining sample) was filtered through a 1 µm GF filter to eliminate large particles and protozoa[3], and added to each 0.2 µm filtered sample. A sample blank for each sample was created using boiled tap water and adding respective inoculum. The samples and blanks were filtered with 0.45-µm GF filter prior to UV-vis spectrophotometry and total organic carbon (TOC) analyses. Biodegradable dissolved organic carbon (BDOC) was determined by measuring dissolved organic carbon (DOC) on a Shimadzu TOC-VCSH (Shimadzu Scientific Instruments, Columbia, MD). A measurement was taken at the beginning of the experiment and 28 days. The following equation was used to calculate the BDOC (Equation 1):

$$\mathrm{BDOC} = (\mathrm{DOC}_{\mathrm{initial,sample}} - \mathrm{DOC}_{\mathrm{final,sample}}) - (\mathrm{DOC}_{\mathrm{initial,blank}} - \mathrm{DOC}_{\mathrm{final,blank}}) \qquad (1)$$

Additionally, the filtered samples were also analyzed with a Lambda-14 UV spectrophotometer (PerkinElmer Inc., Waltham, MA). The Specific Ultraviolet Absorbance (SUVA, Equation 2) is then calculated from the UV absorbance (UVA) at 254nm and DOC data:

$$\mathrm{SUVA} = \frac{\mathrm{UVA254}}{\mathrm{DOC}} \tag{2}$$

The UVA at 254nm of the sample in cm^{-1} is divided by the DOC of the sample, and it is reported in units of m^{-1} L mg^{-1}. SUVA is an indicator of dissolved organic matter aromaticity, providing some information on the DOC characteristics.

Results and Discussion

Results showed that the wetland sample had significantly more DOC than that of the lake (Figure 1, A). This indicates that the wetland leaches DOC, including BDOC, as the concentration of DOC and BDOC were over twice and four-fold than the lake, respectively. This demonstrates that even though a wetland can add contaminant treatment to the lake captured stormwater, its effluent requires an extra unit-process to lower the DOC content. Additionally, geomedia chosen for this study clearly outperformed sand in DOC removal. Geomedia-containing columns were able to achieve >70% DOC reductions. Although sand columns showed no or very little DOC removal, they successfully removed most of the BDOC (especially in the re-aerated second columns). The sequential sand system treating lake water, with less initial BDOC than the analogous wetland water, completely removed BDOC. Regarding geomedia columns, UVA and DOC values decreased simultaneously. Hence, both initial SUVA (0-day) and DOC decreased during the passage through the sequential system. This behavior may be attributed to refractory DOC adsorption onto biochar while BDOC fraction was consumed by microorganisms. In most cases when effluents still contained BDOC, the SUVA for the 28-day sample was higher than the SUVA for the 0-day sample. A higher SUVA, at the wavelength used (254 nm), implies a higher proportion of aromatic functional groups in the DOC, which in turn indicates that a higher portion of the DOC remaining is refractory. Results from this experiment support the idea that including a geomedia-amended biofilter to polish stormwater wetland effluent prior to managed aquifer recharge practices could be beneficial.

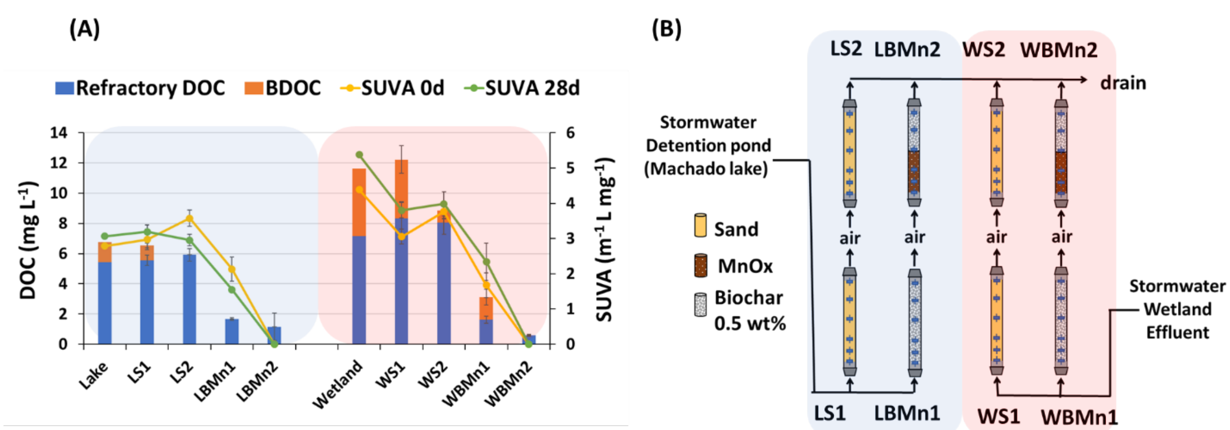

Figure 1. (A) BDOC Results. (B) Column diagram for the field setup.

References

[1] Los Angeles County Flood Control District, City of Los Angeles Department of Public Works Bureau of Sanitation, 2014. Sun Valley Watershed: Rory M. Shaw Wetlands Park Factsheet (Factsheet).

[2] J. Müller, J.E. Drewes, U. Hübner. Water Res. 127 (2017) 127-138

[3] Servais, P., Anzil, A., & Ventresque, C. (1989). Simple method for determination of biodegradable dissolved organic carbon in water. Applied and environmental microbiology, 55(10), 2732–2734.