Laboratory Measurements of Hydraulic Properties of Granular Activated Carbon (GAC)

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Introduction

Granular activated carbon (GAC) is used in water and wastewater treatment plants because of its adsorption properties which are due to its very porous structure, high surface area, and the chemical structure of GAC's surface (Jung et al., 2001). It is widely used to reduce undesirable taste, odor, and color in drinking water (Stewart et al., 1990). It is also used to remove organic contaminants like chlorinated solvents and other industrial pollutants, inorganic materials such as nitrogen and sulfides, heavy metals such as lead and mercury, pesticides, among other contaminants (Brooks et al., 2000). Once GAC is spent, it can either be regenerated and used or sent to a landfill (Brooks et al., 2000). Rather than disposing spent/exhausted GAC in landfills as waste, this study explores the use of GAC from El Paso Upper Valley Water Treatment (UV-WTP), in Anthony, Texas as an amendment to soils for growing riparian vegetation. To test if this particular GAC is a suitable material (i.e. drainage properties) as a soil amendment for growing plants, its hydraulic properties were measured in the laboratory. The ultimate goal of the study is to test the physical and chemical properties of exhausted GAC for safe use as a soil amendment to restore riparian vegetation.

Experimental Methods

This study focuses on the saturated hydraulic conductivity (Ks) and matric potential of GAC. To test these properties, ten 5-gallon buckets of GAC were obtained from UV-WTP and were labeled GAC-1 through GAC-10. A portion of each sample was air dried for more than 24 hours to complete both tests. Hydraulic conductivity was measured using a constant head permeameter following the American Society for Testing and Materials (ASTM) standard using the constant head method (Das, 2009). The temperature of water was recorded for each test and later used to adjust Ks for a test temperature of water at 20°C. This was achieved by multiplying the measured Ks by the ratio of viscosity of water at tested temperatures to 20ºC (Das, 2009).

Matric potentials of the GAC at specific volumetric water contents (VWC) were measured using a WP4C Dewpoint PotentiaMeter (Decagon Devices, Pullman, WA). The VWC was measured using a reflectometer (model CS655 by Campbell Scientific, Logan, UT).

Results

The Ks values measured ranged from 0.014 cm/s to 0.025 cm/s with a mean of 0.019 cm/s and a standard deviation of 0.004 cm/s (n=10 samples). The measured values for each sample of GAC are shown in Table 1. Differences in results may have occurred from a difference in compaction of the GAC in each sample during experimentation. The Ks of GAC is comparable to that of sand which ranges from 0.001 cm/s to 1.0 cm/s (Ren & Santamarina, 2018). More specifically, the hydraulic conductivity of fine and silty sand ranges in values from 0.001 to 0.1 cm/s and 0.001 to 0.01 cm/s, respectively (Coduto, 1999; Das, 2009).

Table 1. Measured saturated hydraulic conductivities of El Paso UV-WTP granulated activated carbon (GAC)

Sample No.	Saturated Hydraulic Conductivity (Ks) (cm/s)
GAC-1	0.016
GAC-2	0.023
GAC-3	0.019
GAC-4	0.016
GAC-5	0.015
GAC-6	0.014
GAC-7	0.018
GAC-8	0.025
GAC-9	0.021
GAC-10	0.024
Mean	0.019
Standard Dev.	0.004

Matric potential values versus their respective VWC for UV-WTP GAC are shown in Figure 1. These results indicate how much water is available to plants from this material and at what VWC in percentages. The amount of available water for plants is determined based on a soils' permanent wilting point (PWP) and field capacity (FC). These values are different for each soil, but it is generally estimated that the PWP is about -15 bars (-1.5 MPa) and the FC ranges from -0.1 to -0.3 bars (-0.01 to -0.03 MPa) (Mariamma and Babu, 2010). For GAC, the PWP occurs at a VWC of about 15%, while the FC ranged from about 25% to 40% (Figure 1). This is similar to loam soil which has a range of available water from 10% to 35% while sand ranges from 2% to approximately 15% (Mariamma and Babu, 2010). Further testing should be done to clarify the FC of GAC.

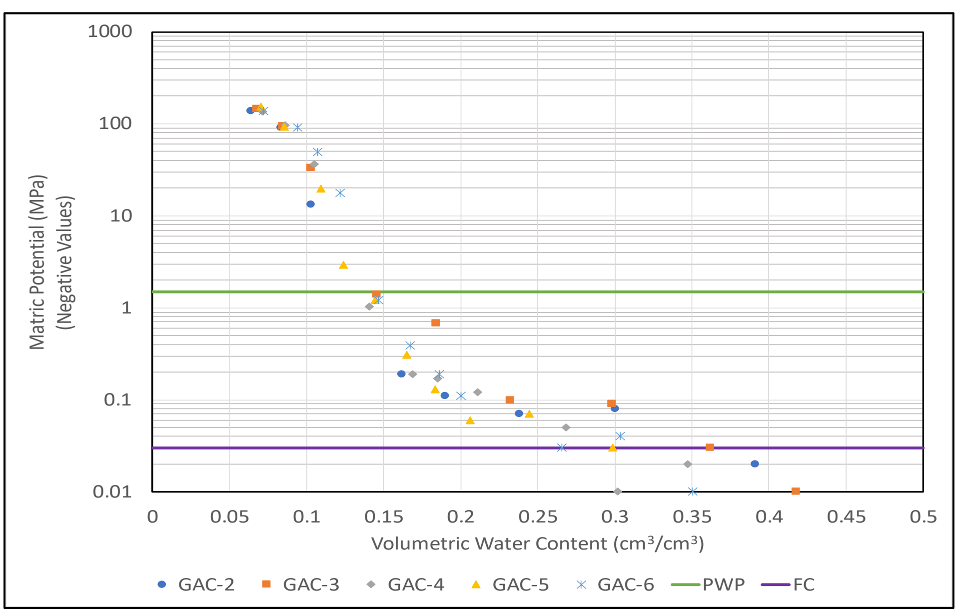

Figure 1. Moisture characteristic curve for El Paso UV-WTP granular activated carbon (GAC)

Conclusion

The saturated hydraulic conductivity (Ks) of exhausted GAC from UV-WTP measured is comparable to that of sand, and more specifically for fine or silty sand. A GAC MCC was also developed, and is most similar to loam with a range of about 10% to 25% available water for plants. These hydraulic properties indicate good soil drainage and a low matric potential at volumetric moisture contents ranging from 20% to 40%, both of which are suitable for plant growth. Future testing should include capillarity to better understand GAC's use as a wicking material and chemical testing to better understand what types of nutrients or chemicals may be added to soil as the GAC has been previously used for water treatment. GAC as a material is widely known for its adsorbent properties, however its potential for use in this field is undiscovered.

References

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