Biosand Filter: Investigation of Sand Size and Distribution on Filter Performance

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Background

- Because access to a laboratory balance can be a challenge when constructing a biosand filter (BSF) in a developing region, the Centre for Affordable Water and Sanitation Technology (CAWST) has developed a field protocol for measuring important sand characteristics using a grain size distribution curve based on the volume (rather than mass) of sand captured on each sieve (**Figure 1**).
- Sieve tests are used to quantify the range of grain sizes within a sand sample intended for use in a BSF
- Important sand characterization parameters:
  - d_{10} (Effective Size): 10% of the sand sample is finer than the mesh size, recommended to be 0.15-0.20mm
  - d_{60}: 60% of the sand sample is finer than the mesh size
  - UC (uniformity coefficient): ratio of d_{60} to d_{10}, recommended to be 1.5-2.5
  - These parameters are important in attaining the target BSF flow rate of 400 mL/minute

Research Objectives

- Determine if the d_{10} and UC of sand samples are comparable when the sand grain analyses are based on mass versus volume
- Monitor the performance of pilot-scale BSF columns as a function of the d_{10} and UC (performance indicators include turbidity and *Escherichia coli* removal)

Methods

- Five sand samples were washed and dried according to the protocols provided in the CAWST "Biosand Filter Construction Manual"

Figure 2. Five types of sand tested in this study

From left to right: (**Figure 2**)

Sample 1 (S1) = Quarry/Sandbox Sand
Sample 2 (S2) = Beach Sand
Sample 3 (S3) = Angular Sand
Sample 4 (S4) = Reused BSF Sand (recovered from deconstructed BSFs)
Sample 5 (S5) = Concrete Sand

- Grain size analyses were then performed on samples following the CAWST volumetric protocol

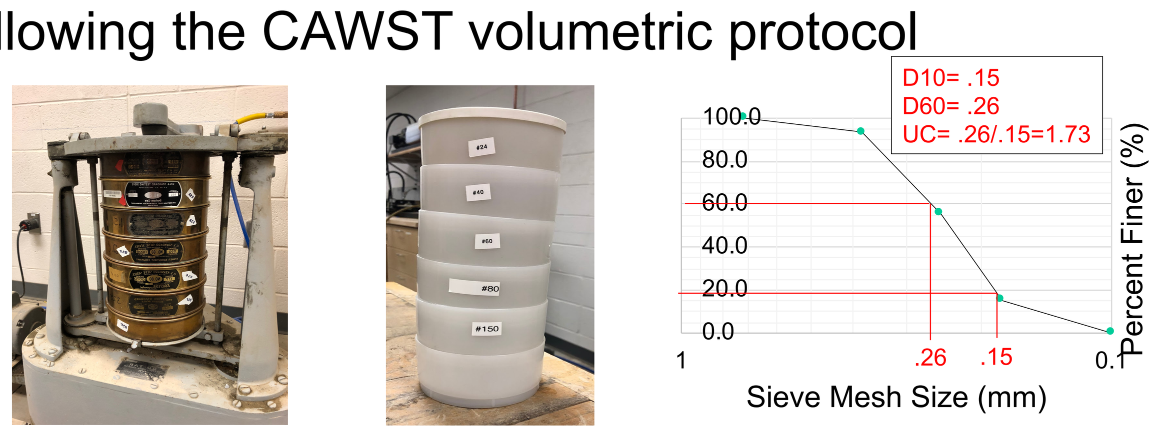

Figure 1. Left Panel: laboratory sieves, Center Panel: CAWST sieves, Right Panel: sample sand grain distribution curve based on sand sample 1 by volumetric-field method

- Ten pilot-scale sand columns (**Figure 3**), designed to replicate a CAWST biosand filter, were filled with tested sand samples (duplicate columns for each sand type)

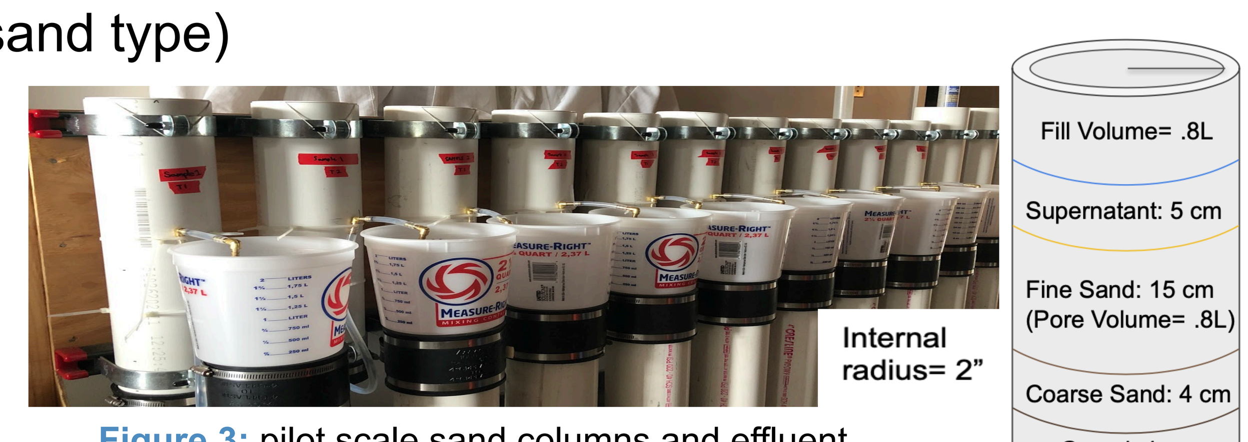

Figure 3: pilot scale sand columns and effluent collection system, diagram of internal sand column

- Flow rates and turbidity removal were tested daily using an 800-mL influent volume of Monocacy Creek water
- *E. coli* removal was tested weekly using membrane filtration and colony counts on m-ColiBlue24 media

Results and Discussion

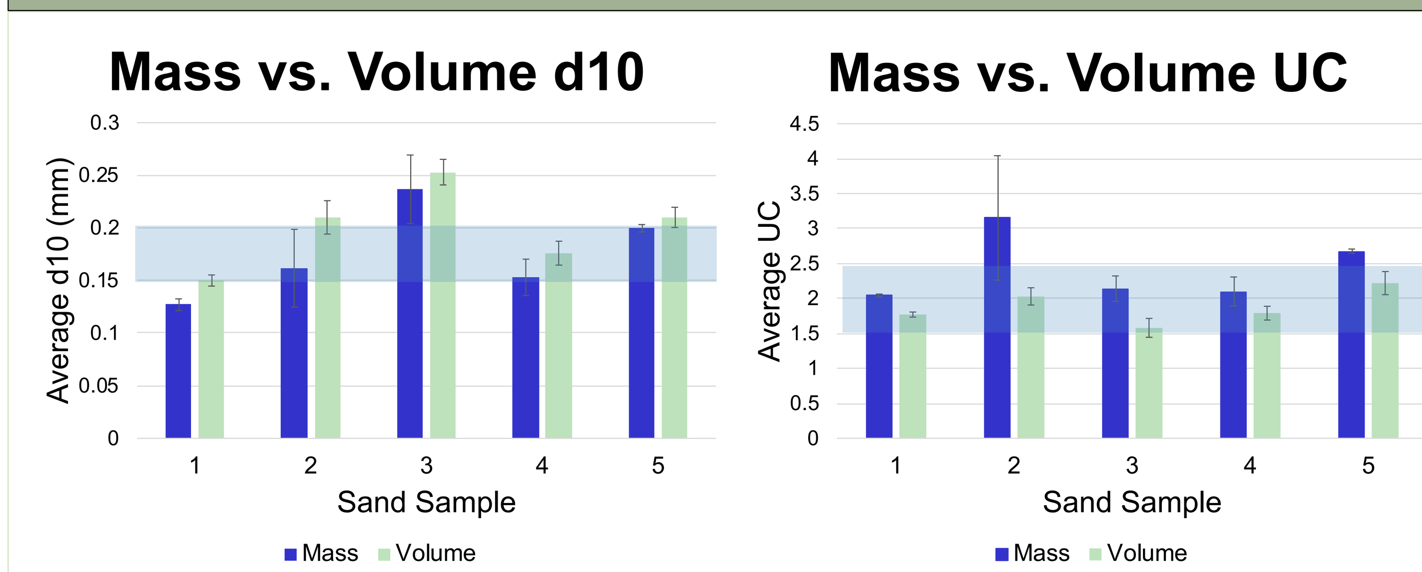

Figure 4. Average d10 and UC measurements for each sand type based on mass versus volume. Error bars are ± standard deviation, n=3 for each measurement. Light blue shaded region indicates recommended range for BSF sand.
Note: Mass measurements taken using laboratory sieves, volume measurements taken using CAWST sieves

- Average d_{10} was greater (not significantly) when using the volumetric field method (**Figure 4**)
- Average UC was significantly greater when using laboratory mass method (**Figure 4**)
- Unmet parameters: (**Figure 4**)
  - S1: d_{10} below recommended range (by mass)
  - S2: UC above recommended range (by mass)
  - S3: d_{10} above recommended range (by mass and volume)

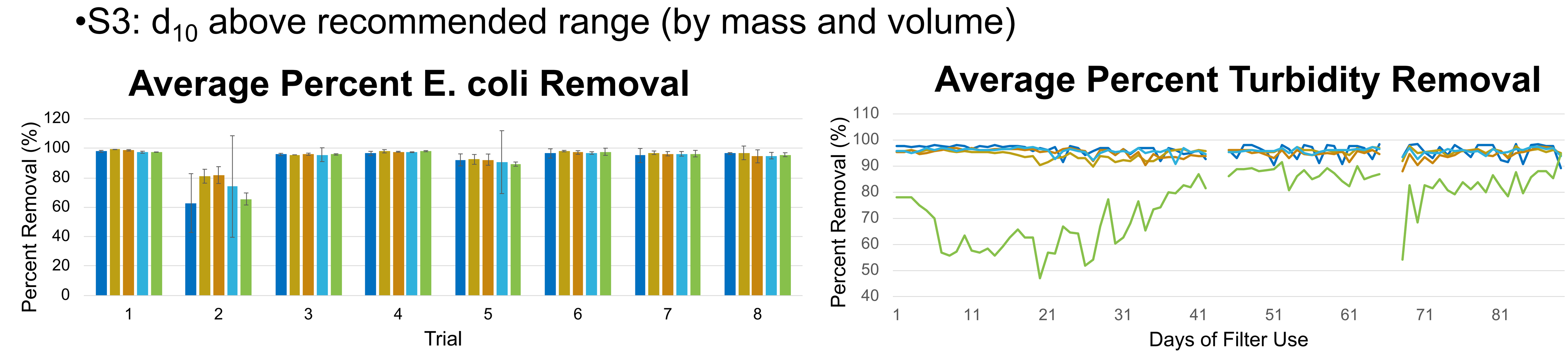

Figure 5. Left Panel: Average percent E. coli removal for each sand sample. Error bars are ± standard deviation, n=2 for each sand sample, Right Panel: Average percent turbidity removal for each sand sample. n=2 for each sand sample.
Note: Breaks in graph from academic break and sand column cleaning, respectively

- E. coli: All of the sands performed similarly with respect to E. coli removal (**Figure 5**)
- Turbidity Removal: Sample 5 consistently removed the least turbidity (**Figure 5**)

Conclusions

- The sand that performed the best in contaminant removal did not meet d_{10} and UC standards
- When using the CAWST volumetric method, the d_{10} measurements were larger and the UC measurements smaller than the laboratory mass method
- Inaccurate d_{10} and UC standards may negatively affect the drinking water quality of those using BSFs for water purification

Future Outlook

- Additional sand grain analysis trials should be run to enable use of the Mann-Whitney nonparametric test for more accurate determination of statistical significance
- A report on CAWST protocols and sand grain standards will be written and shared with the organization

References

1 . *Centre for Affordable Water and Sanitation Technology* (CAWST). 2012. "Biosand Filter ConstructionManual."p.9-57. https://resources.cawst.org/construction-manual/a90b9f50/biosand-filter-construction-manual?resLang=en. PDF. Accessed 1 Mar, 2019.

2. *Centre for Affordable Water and Sanitation Technology* (CAWST). 2019. "Sand." https://www.biosandfilters.info/topic/sand. Accessed 1 Mar. 2019.

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