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

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Introduction

Many developing countries lack the resources to purify their drinking water effectively and on a full scale. As a result, people turn to alternative technologies, such as biosand filters (BSFs), to produce potable water. The size of the sand used in the BSF is recognized as a critical parameter in the optimal performance of the filters. Guidelines for the effective sand size (ES) and the sand size distribution (represented by the uniformity coefficient, UC) have been established for BSFs. The ES and the UC are calculated from a sand size distribution curve, which is generated by sieving a sand sample of known mass and recording the mass of sand that accumulates on sieves of different sizes. Because access to a laboratory balance is a challenge when constructing a BSF in a remote, developing region, the Centre for Affordable Water and Sanitation Technology (CAWST) has developed a field protocol for measuring the ES and UC using portable field sieves (Figure 1) and a sand size distribution curve based on the volume (rather than mass) of sand captured on each sieve. The goal of this study is to determine whether a significant difference occurs in grain size analyses between the CAWST field method (based on volume) and the generally accepted laboratory method (based on mass).

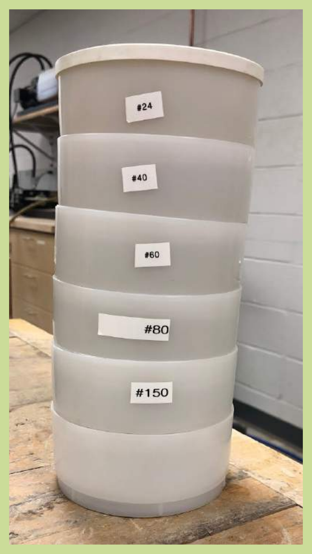

Figure 1, CAWST field sieves.

Research Objectives

- Determine if the ES 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 (Figure 2) as a function of the ES and UC (performance indicators include flow rates as well as removal of turbidity and *Escherichia coli*)

Figure 2, Pilot scale sand columns and effluent water collection system

Methods

Five different sand samples were washed and dried according to the protocols provided in the CAWST "Biosand Filter Construction Manual." Grain size analyses were performed on the five sand samples using both the CAWST volumetric protocol (n=3) and the more generally accepted mass analysis (n=3). To test sand efficacy, ten pilot-scale BSF columns (duplicate columns constructed with one of the five sand samples tested; Figures 2 and 3) were designed and constructed to replicate a CAWST BSF.

The filters were filled daily with water from the Monocacy River (ranging 18.0-25.0 NTU), and the following tests were performed on the columns:

- Flow rate and turbidity removal (daily)
- *E. coli* removal using membrane filtration and colony counts on m-ColiBlue24® media (Figure 4; weekly)

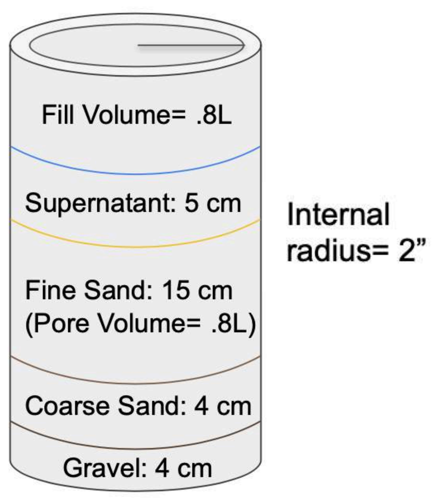

Figure 3, Diagram of pilot scale BSF columns

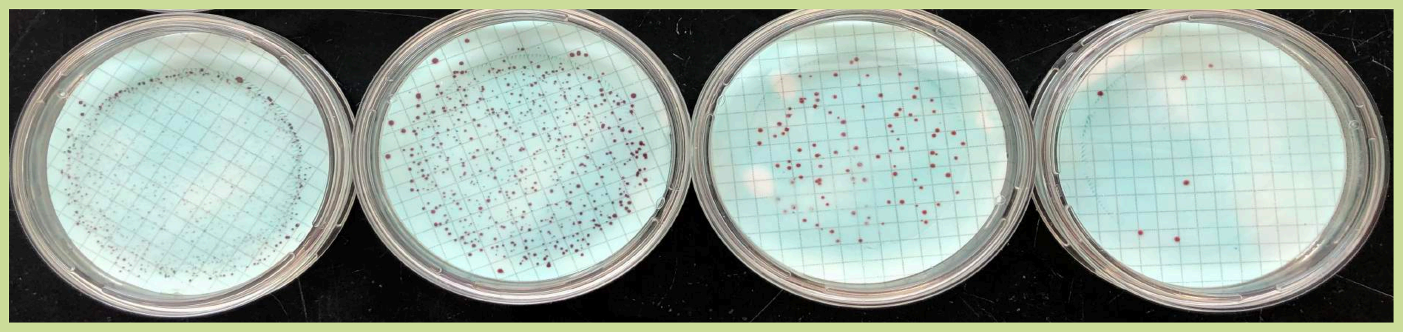

Figure 4, Plates of *Escherichia coli* on m-ColiBlue® media

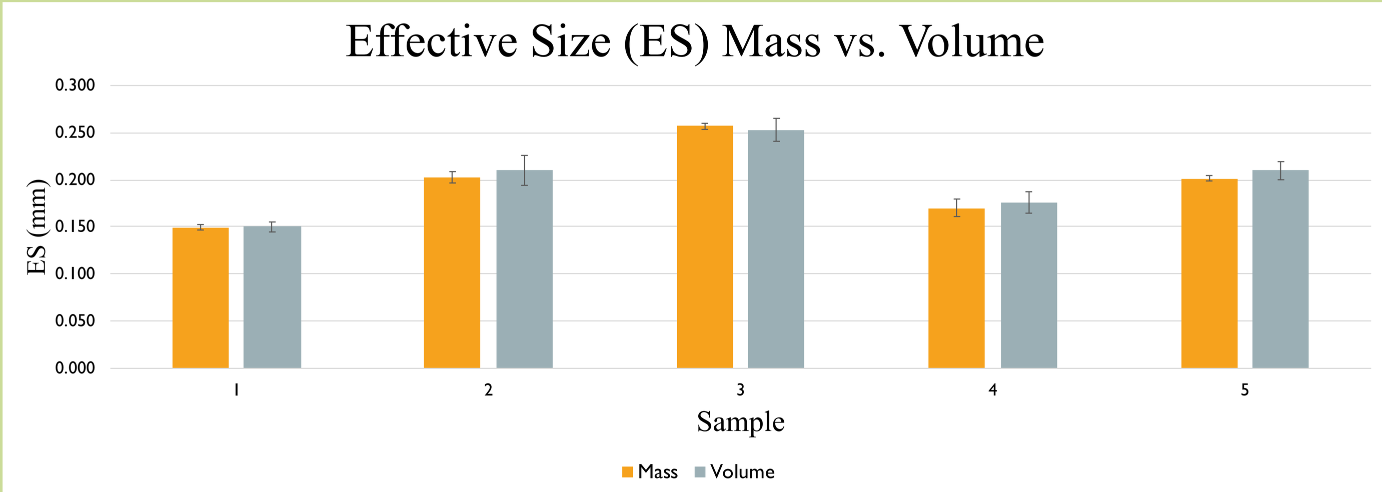

Figure 5, Comparison of ES using lab (mass) and field (volume) methods
Note: Recommended ES for BSFs is .15-.20 mm

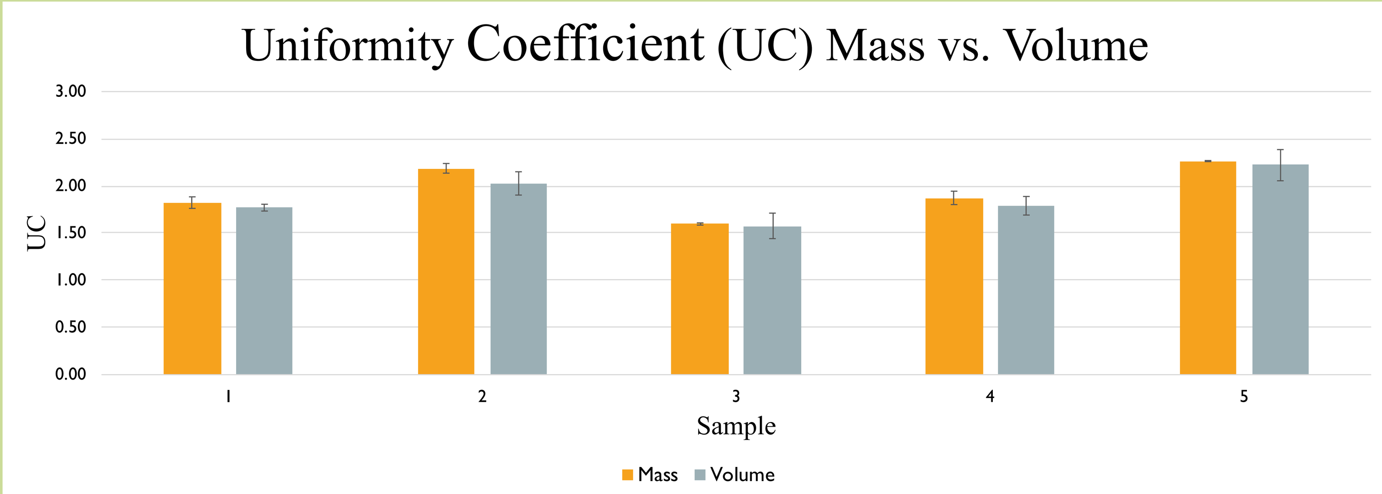

Figure 6, Comparison of UC using lab (mass) and field (volume) methods
Note: Recommended UC for BSFs is 1.5-2.5

Table 1, Determination of sand samples that fall within recommended standards
Note: all ES and UC calculations determined based on volume

Sample	Average ES (mm)	Within range?	Average UC	Within range?
1	.150	Yes	1.8	Yes
2	.210	No	2.0	Yes
3	.253	No	1.6	Yes
4	.176	Yes	1.8	Yes
5	.210	No	2.2	Yes

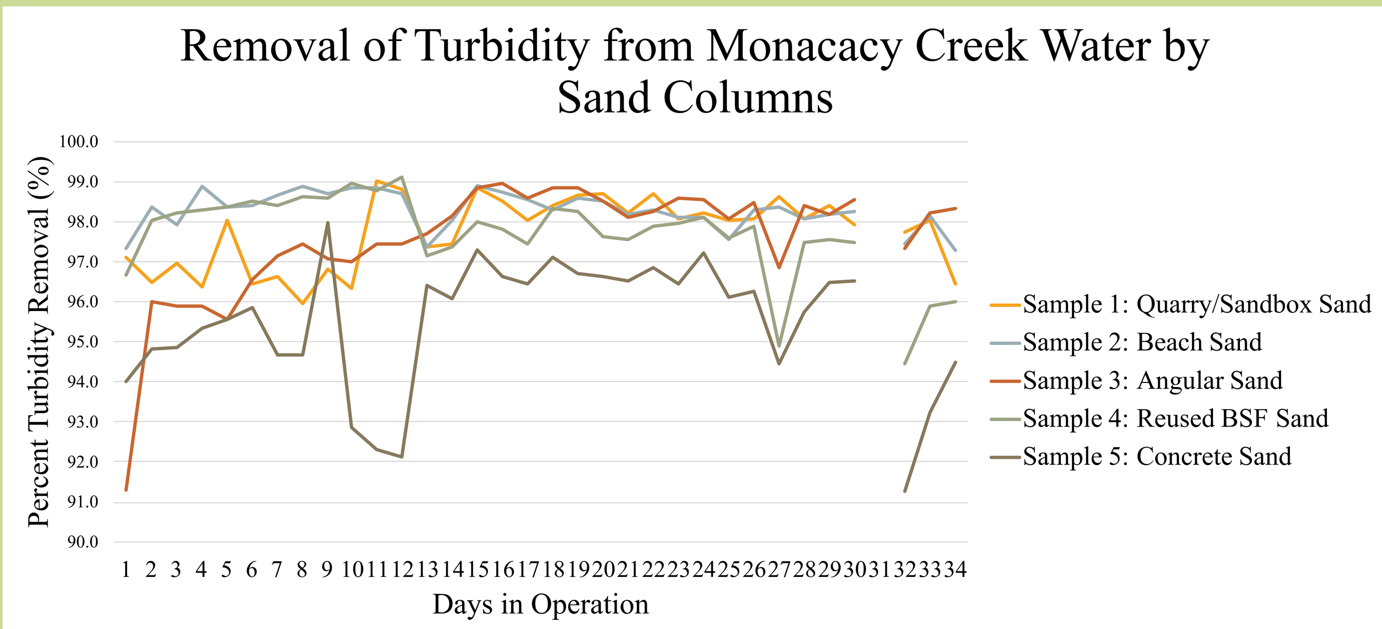

Figure 7, Percent turbidity removal by sand columns

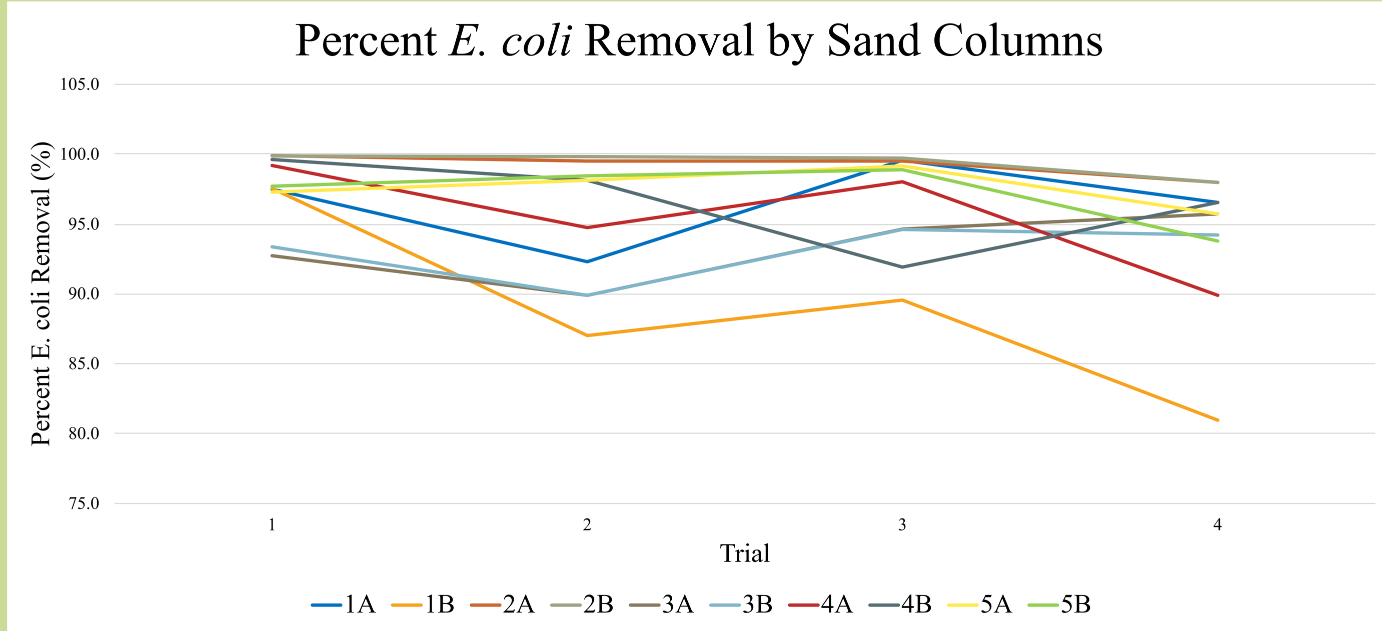

Figure 8, Percent *Escherichia coli* removal by sand columns
Note: First trial spiked with 8200 mL spike volume, not standard 9800 mL

Results and Discussion

- There is not a significant difference between ES and UC calculated based on mass or volume (Figures 5 and 6)
- The ES (mm) for samples 2, 3, and 5 do not fall within the recommended range (Table 1)
- Sand Sample 2 had the most efficient turbidity (Figure 7) and *E. coli* (Figure 8) removals

Conclusions

- There is not a significant difference in the grain size distribution results between the CAWST method (based on volume) and generally accepted laboratory method (based on mass)
- The ES and UC standards should be reviewed since the best performing sand in our study did not meet the ES standard
- Inaccurate ES and UC standards may negatively affect the drinking water quality of those using BSFs for water purification

Future Outlook

- Testing will continue on the sand columns
- Additional sand grain analyses 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
- A review of the CAWST sieves (Figure 1) and challenges of using them will be included in the report

Acknowledgments

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1. *Centre for Affordable Water and Sanitation Technology* (CAWST). 2012. "Biosand Filter Construction Manual." 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.