Laboratory and Field Methods Developed for Biosand Filter and Sand Characterization

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ABSTRACT

Many developing countries lack the resources and funds needed to effectively purify their drinking water using traditional, centralized, large-scale water treatment processes. As a result, people turn to alternative household treatment technologies, such as biosand filters (BSF), to produce potable water. The Centre for Affordable Water and Sanitation Technology (CAWST) has developed a field protocol for measuring key BSF performance parameters of sand using portable field sieves and a sand size distribution curve based on the volume (rather than mass) of sand captured on each sieve. Although this protocol is widely accepted, there has been little investigation into whether the CAWST field method is an acceptable alternative to the laboratory (mass) method. This study investigates variations in laboratory and CAWST methods to characterize BSF sand.

INTRODUCTION

- Sand parameters quantify the grain size variation and distribution in a sand sample
- The following are key parameters that indicate a sand sample's ability to achieve a target flow rate and remove contaminants in drinking water :
  - **Effective Size (ES or d_{10}):** sieve mesh size at which 10% of the sand sample passes through the opening, recommended to be 0.15- 0.20 mm
  - **d_{60}:** sieve mesh size at which 60% of the sand sample passes through the mesh opening
  - **Uniformity Coefficient (UC):** ratio of d_{60} to ES, recommended to be 1.5- 2.0

Figure 1. Left Panel: CAWST (hand-held) field sieves, Right Panel: laboratory sieves

- The recommended ES and UC ranges were determined using laboratory sieves and particle size distribution (PSD) curves based on mass measurements (Figure 1)
- The CAWST field protocol uses hand-held sieves and PSD curves based on volume measurements (Figure 1)

OBJECTIVES

Determine if a sample's ES and UC are comparable when using:

1. Mass versus volume as the basis for particle size distributions
2. CAWST hand-held sieves (analysis completed) versus laboratory sieves (analysis in progress)
3. Three calculation techniques: computer-drawn PSD curves, hand-drawn PSD curves, a CAWST application

METHODS

- Five sand samples were prepared according to CAWST's *Biosand Filter Construction Manual* (Figure 2)

Figure 2. Five sand samples analyzed, in ascending order from Sample 1 on far left to Sample 5 on far right

- Each sand sample was analyzed in 17 independent trials
  - Particle size distribution analyses were performed using mass and volume measurements, respectively, using the CAWST hand-held sieves according to the CAWST field protocol
  - Mass-based and volume-based ES and UC were calculated for each trial using the three calculation techniques (Figure 3)

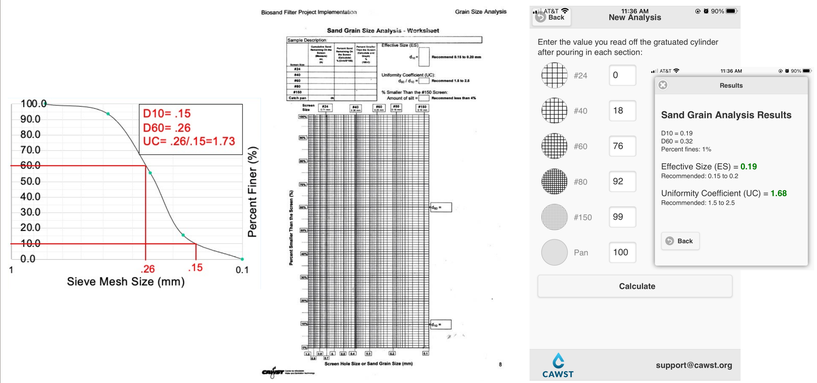
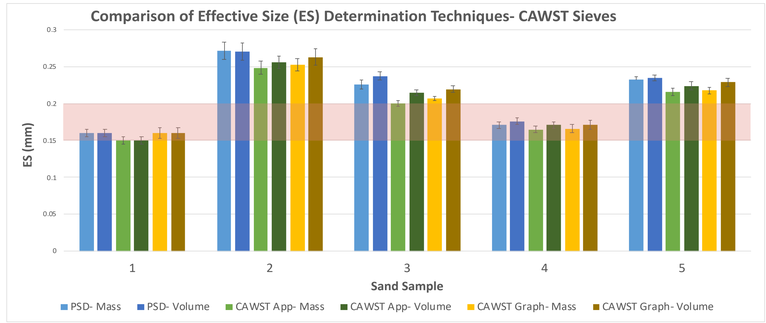


Figure 3. Left Panel: example computer-drawn PSD and ES and UC determination, Center Panel: Hand-drawn PSD Graph paper (included in CAWST BSF Manual), Right Panel: screenshots from CAWST Biosand Filter Sand (BSF) App (currently not available in US Apple App Store)

- The Kruskal-Wallis H Test and the Mann-Whitney Nonparametric U-Test Are Performed using a significance level (α) of 5% to determine if there was a statistically significant difference between mass-based and volume-based ES and UC values for each calculation method

RESULTS

- The ES and UC resulting from mass and volume measurements are similar for each of the three calculation methods (Figure 4)



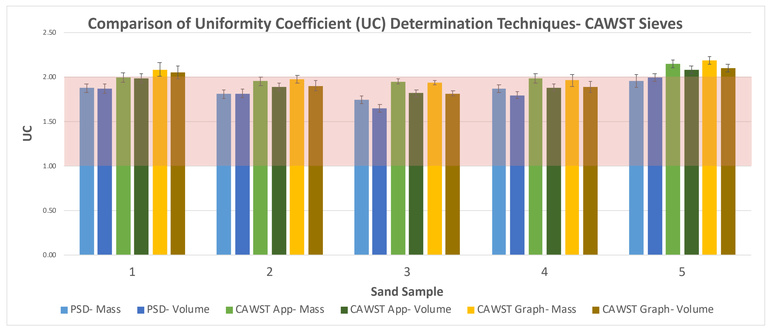


Figure 4. Top Panel: Average ES for each sand type based on parameter determination methods, Bottom Panel: Average UC for each sand type based on parameter determination methods. Error bars are ± standard error, n=17 for each measurement. Light red shaded region indicates recommended ES and UC ranges for BSF sand.

- The Mann-Whitney test suggests no significant difference between the mass and volume parameters for samples 1, 2, 4, and 5. Sample 3 showed a significant difference between mass- and volume- based parameters
- For some of the sand samples, significant differences were found between the ES and UC calculated according to the three different methods (computer-drawn PSD, hand-drawn PSD, and CAWST app; Kruskal-Wallis $p < 0.05$).

CONCLUSIONS

- The ES and UC values determined using mass and volume are similar when using the CAWST hand-held sieves
- Generally, there is no significant difference between mass- and volume-based parameters for each calculation method
- The ES and UC values are sometimes statistically different between the three calculation techniques

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