Performance of Intermittently Operated Slow Sand Filters in Rural Schools in Cambodia

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INTRODUCTION

Safe drinking water is important in a school environment, as children are often vulnerable to water-born disease. Schools in low income settings present a challenging context for the provision of safe water. There are many environmental (e.g. poor water quality), technological (e.g. little technical knowledge) and practical (e.g. no electricity) challenges to having sustained access to safe water.

In 2012, Samaritan's Purse and Clear Cambodia began implementing intermittently operated slow sand filters as an appropriate, sustainable solution to improve water quality in rural schools in Cambodia. At the end of 2015, 170 of these filters were installed in schools in 7 provinces of Cambodia.

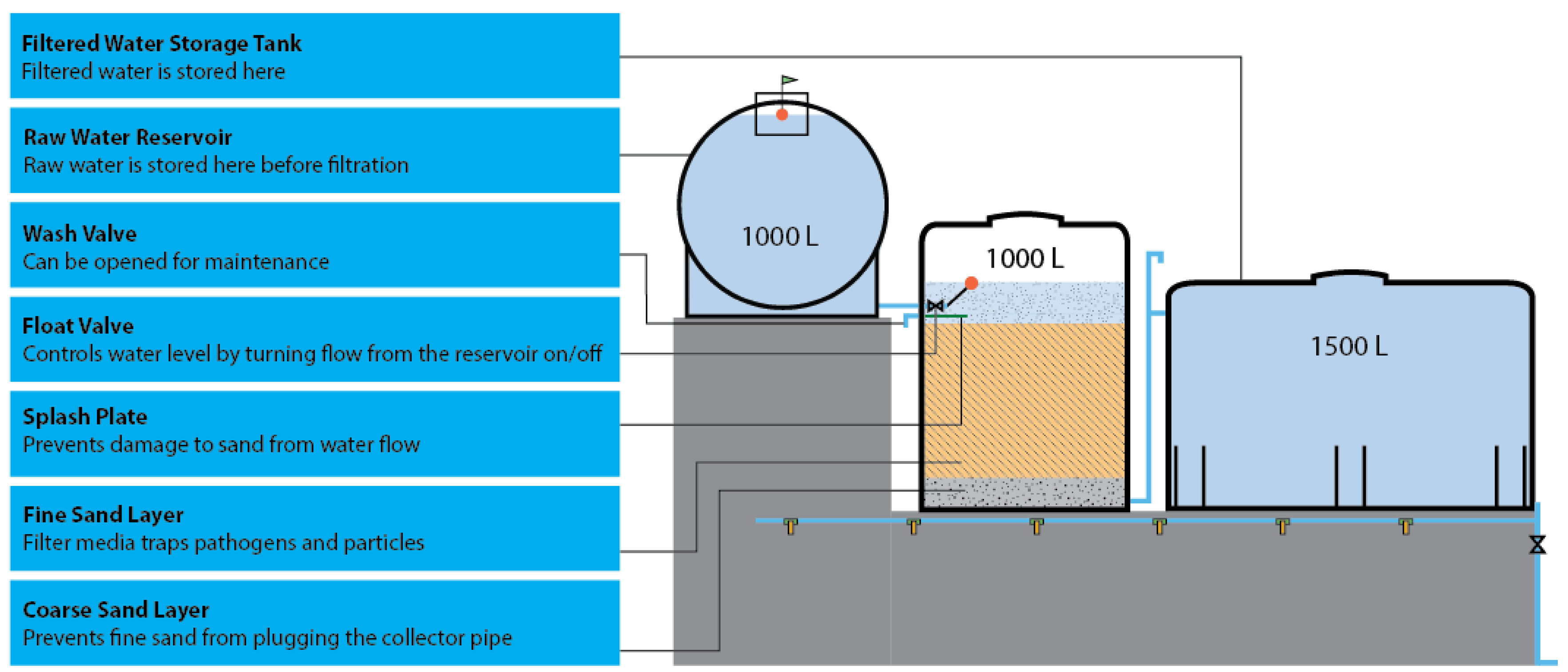

Figure 1. Schematic of an intermittently operated slow sand filter

The intermittently operated slow sand filters considered in this study were composed of three tanks; a 1000 L raw water reservoir, a 1000L vertical tank with sand as a filter medium and a 1500 L filtered water storage tank. Water is pumped (manually or by motor) to the raw water storage tank. Raw water flows by gravity to the filter. The driving water head above the filter is limited to 20 cm by a float-controlled valve. The vertical tank is filled with 75 cm of filtration sand, (effective size of 0.15-0.20 mm; uniformity coefficient of 1.5-2.5; silt content < 4%) which is supported by 15 cm of coarse sand. Water is filtered at a peak hydraulic loading rate of 0.2 m/h. This is approximately a quarter of the hydraulic loading rate of a household BioSand filter. Filtered water is collected from the coarse sand via a PVC perforated pipe underdrain. The water is propelled up the PVC riser pipe and over a weir to an integrated filtered water storage where the water is then available on demand from taps. The filter has the capacity to produce over 3,000 L/day, if operated continually. This could provide each student with 10 L of filtered water per day for a school of 300 students.

METHODS & MATERIALS

The primary objective of the study was to document the quality of the water produced and the performance of the filtration system to improve microbiological, chemical and physical parameters of the water. *E. coli* samples for source water, filtered water and stored water were collected by spot checking and were analyzed by an Aquagenx Compartment Bag Test. These samples were collected by field staff during monitoring visits between January 2014 and August 2015 (n=172).

In addition, the following parameters were considered in an independent spot check conducted in January 2015 at 24 schools four provinces (Kompong Chhnang, Kompong Thom, Prevy Veng and Svay Rieng): *E. coli*, turbidity, pH, UV absorbance at 254 nm, nitrate, nitrite, ammonia, conductivity, total hardness, and calcium concentration. Turbidity, pH and conductivity were analyzed onsite. The remaining tests were conducted at the Resource Development International laboratory near Phnom Penh, Cambodia.

Figure 2: Typical slow sand filter installation

RESULTS & DISCUSSION

Filtered Water Quality

- Mean raw water *E. coli* was 28.2 colonies/100 mL lower than typically reported in rural Cambodian household water supplies.
- Mean filtered water *E. coli* was 4.1 colonies/100 ml.
- Mean *E. coli* removal rate of 97.8% was found when considering only the data where source water *E. coli* was 5 colonies/100 mL or greater (n = 66).
- This *E. coli* removal rate is higher than typically reported for household BioSand Filters (e.g. 90%[1]), and is consistent with expectations of approximately 2-log for a slow sand filter based on the literature[2].
- 75% of the filtered water samples had no *E. coli,* and 95% of the samples (188 of 198) had < 10 *E. coli* colonies in 100 ml.
- Mean filtered water turbidity was 0.56 NTU (n=24), which is below the WHO guideline of 1 NTU.
- The mean turbidity removal was 82%.
- Mean UV absorbance at 254 nm decreased from 0.047 cm^{-1} for raw water to 0.029 cm^{-1} for filtered water (38% removal, n = 24), suggesting the some organics removal.
- Mean calcium levels increased from 43 mg/L as $CaCO_3$ in the raw water to 71 mg/L as $CaCO_3$ in the filtered water (n=24). As calcium hardness is an aesthetic concern to many users, calcium leaching from the filter sand warrants further investigation.

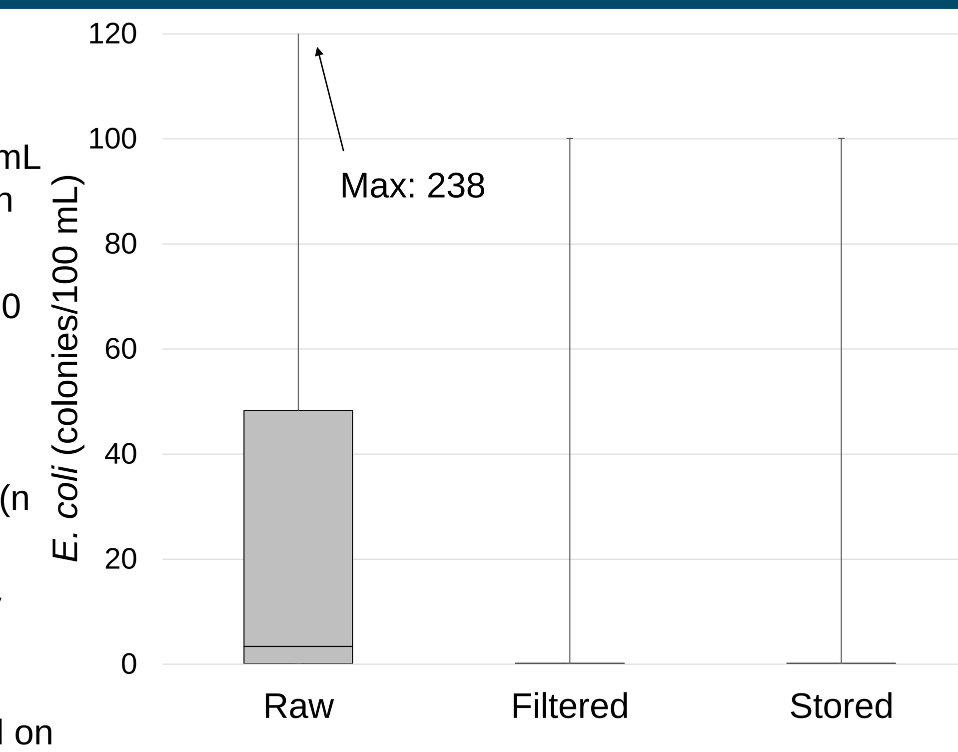

Figure 3: Summary of *E. coli* results (n=198)

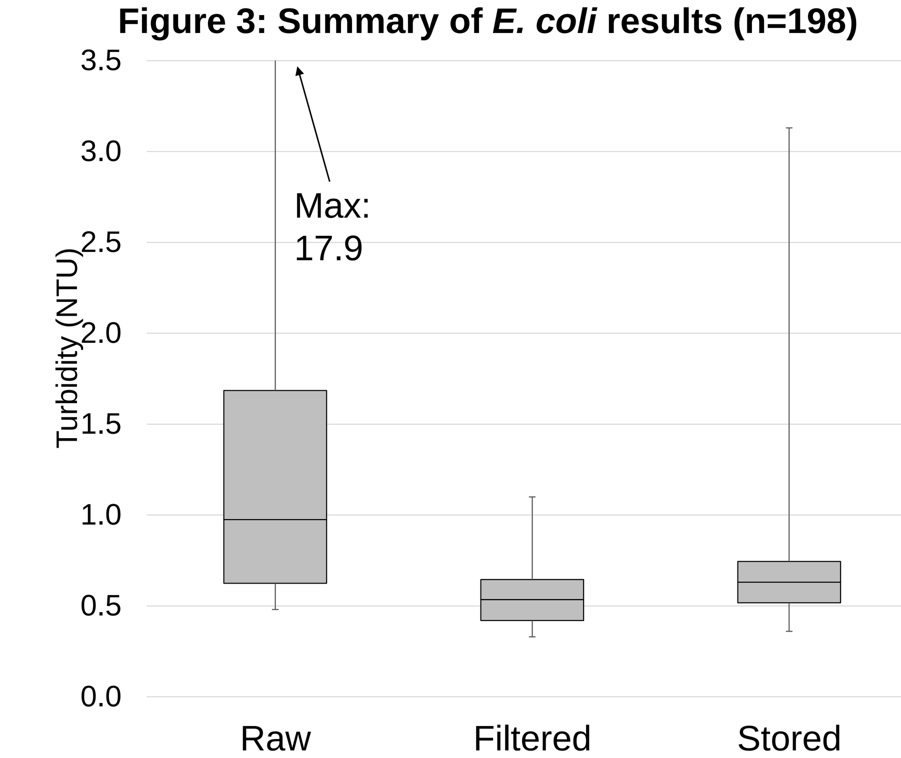

Figure 4: Summary of *Turbidity* results (n=24)

- No changes in conductivity (p=0.44), total hardness (p=0.14) or temperature were observed across the filter or during storage (n=24).
- No change in ammonia, nitrate or nitrite levels was observed, possibly owing to low ammonia levels in the raw water (Mean < 0.05 mg/L as NH_3, n=24).

Stored Water Quality

- The mean stored water *E. coli* was 3.8 colonies/100 ml. 75% of the stored water samples had no *E. coli* and 95% of the samples (188 of 198) had < 10 *E. coli* colonies in 100ml, similar to the filtered water. Only 14% of stored water samples (27 of 198) had *E. coli* levels greater than the filtered water. Taken as a whole, there is little evidence of contamination or growth during storage.
- Mean stored water turbidity increased by 0.32 NTU to 0.87 NTU (n=24), but remained below the WHO guideline of 1 NTU for 88% of the samples (21 of 24).

References

1. Ngai T.K.K., B. Coff, D. Baker, R. Lentz (2014). Global Review of the Adoption, Use and Performance of the Biosand Filter in *Progress in Slow Sand and Alternative Biofiltration Process*. IWA Publishing pp 309-317.
2. Ellis K.V. and Wood W.E. (1985). Slow sand filtration. *Critical Reviews in Environmental Control*, 15 (4): 315-354.

CONCLUSIONS

- An *E. coli* removal rate of 97.8% was measured across the filter (n = 66); this is better removal than typically reported for household BioSand Filters and is consistent with 2-log removal in the literature for slow sand filters.
- A mean turbidity removal of 82% was observed resulting in a mean filtered water turbidity of 0.56 NTU, below the WHO guideline of 1 NTU.
- Mean calcium levels increased from 43 mg/L as $CaCO_3$ in the raw water to 71 mg/L as $CaCO_3$ in the filtered water, warranting further investigation around calcium leaching from the sand medium.
- No changes in conductivity, total hardness, temperature, ammonia, nitrate or nitrite levels were observed across the filter.

This data, collected for filters between 1 and 12 months after installation, indicates that the filter meets design expectations for the removal of E. coli and turbidity. The long term (> 1 year) performance of this intermittently operated slow sand filter when raw water E. coli or turbidity levels are higher should be determined.