System-level, Automatic Chlorination in Community-managed Water Systems

The effectiveness of in-line, passive chlorination technologies are investigated as part of a larger study that aims to improve piped water systems in rural Nepal. This article describes the selected technologies used and reports on baseline results of microbial water quality. Y. Crider[1], S. Sainju[2], R. Shrestha[3], G. Clair-Caliot[4], A. Schertenleib[4], M. Bhatta[3], S.J. Marks[4], I. Ray[1]

Introduction

Access to safe drinking water is recognised as both an essential human right and a public health priority, and the United Nations Sustainable Development Goals call for access to microbiologically safe drinking water for all by 2030. The dominant strategy for low-cost safe water treatment has been promotion of household-level treatment methods, for example, household filters, solar disinfection (SODIS), boiling, or chlorine products. However, this approach has notable limitations. The daily burden of treatment falls on the household, often to women and girls, and products must be maintained or repurchased, a separate added task for busy, low-income households. Unsurprisingly, correct, consistent, and long-term use of these treatment products is typically quite low [1]. In recent years, a growing number of low-cost chlorination technologies have been developed for system-level, automatic water treatment. These may be especially appealing for small, rural systems, which often have limited technical and managerial capacity for sustaining the operation of complex treatment systems. Furthermore, residual levels of chlorine protect drinking water from recontamination during distribution and storage, an important benefit where water is intermittently supplied, which is a common characteristic of small, piped water systems.

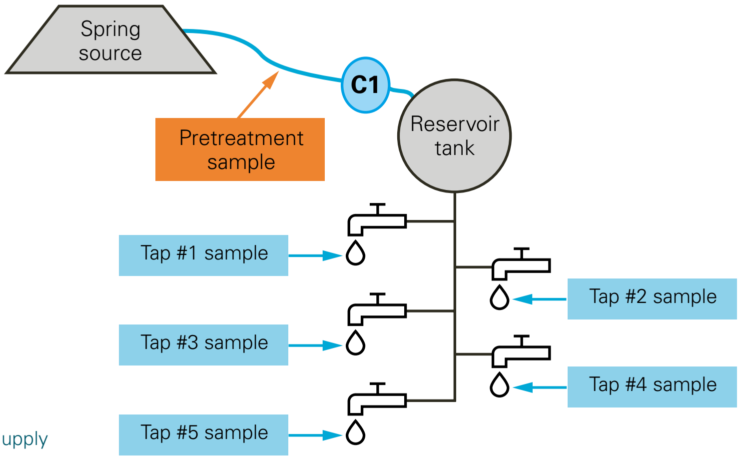

Figure: Piped water supply sampling locations.

Overview of methods

This study is implemented in a rural area of Nepal. The selected communities are part of a larger study, run by Eawag and Helvetas-Nepal, which is implementing and evaluating a risk-based water safety strategy for gravity-fed piped schemes in rural Nepal. As part of the larger study, Helvetas has trained local staff in selected communities to manually add powdered bleach to reservoir tanks for drinking water treatment. In the sub-study described here, a sub-set of these communities were selected to test in-line, passive chlorination as an alternative to the manual dosing approach. Six reservoir tanks were selected, each of which supplies piped water to a small distribution system with community taps, and microbial water quality at the system taps was characterised. Reported flowrates were measured in triplicate and averaged. Prior to the installation of chlorination technologies, water samples (100 mL volume) were analysed for *E. coli* and total coliforms at field labs, using solar powered incubators described elsewhere by co-authors [2] (See p. 23). The Figure illustrates the sampling locations within the pipe network.

The results of our baseline assessment of system water quality and flowrates are shown in the Table. At some sites, water at the reservoir tank was free of *E. coli*. However, on average, *E. coli* was detected in water samples collected at taps. Water quality declined further during storage in the household, and, in total, these results clearly indicated a need for additional treatment, such as chlorination.

	E. coli		**Total coliforms**		
	Pretreatment* (log10 CFU / 100 mL) *(n=1 per system)*	**Taps (mean log10 CFU / 100 mL)** *(n=4–6 per system)*	**Pretreatment (log10 CFU / 100 mL)** *(n=1 per system)*	**Taps (mean log10 CFU / 100 mL)** *(n=4–6 per system)*	**Flowrate at reservoir tank inlet (L / min)**
1	0.48	0.26	2.48	1.94	7.0
2	1.11	1.43	2.48	2.48	6.3
3	0	0.24	2.48	1.89	6.6
4	0	0.06	1.08	0.52	5.7
5	1.43	0.22	2.48	2.08	11.2
6	0	1.30	2.48	1.60	6.5

***** Minimum reported value is 0 for log10 transforms of 0 CFU / 100 mL results

Table: Baseline (before chlorinator installation) water quality and flowrate at each system.

Selection and installation of low-cost passive chlorination technologies

Not all passive chlorination technologies are suitable for a given setting, yet little evidence exists to guide technology selection across different settings. Technology


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Photo 1: PurAll 100 chlorinator.

options are differentiated by factors, such as type of chlorine (i.e., solid versus liquid), cost, maintenance frequency, and compatibility with flowrates and pipe size. In these communities, solid chlorine options were determined to likely be best because they are more concentrated than liquid options and easier to transport.

The range of flowrates observed at the reservoir tanks further narrowed technology options, and two tablet chlorine-based, passive technologies were selected to evaluate: PurAll 100 and Aquatabs Flo (Photos 1 & 2). The PurAll 100 chlorinator is manufactured by Easol Ltd. and is imported from India. The cost of all installation materials, including all pipe fittings and excluding chlorine, was 679 USD. The cost of chlorine is 0.06 USD per cubic meter of water treated, assuming a dose of 1 mg/L chlorine. The Aquatabs Flo is manufactured by Medentech Corp. (Wexford, Ireland) and has been evaluated in Bangladesh and installed in many other locations. The cost of all installation materials is 87 USD, with a chlorine cost of 0.16 USD per cubic meter of water treated. The unique characteristics of each site means that the same technology can perform quite differently across even nearby systems. The variability in flow rate (Table) among the small piped systems selected in our study, for example, necessitated slightly different configurations of the same devices in order to achieve the same dosing.

Ongoing and next steps

The data presented here represent a small portion of the study baseline results. For example, other activities include household surveys of user satisfaction and an assessment of household stored water quality. Monitoring will continue of the performance of these devices through fall 2019, which will allow for assessments over nine months of device performance, including analysis of all costs associated with ongoing maintenance.


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Photo 2: Aquatabs Flo chlorinator.

Conclusion

The efficacy of chlorination for drinking water treatment has long been known, and much of the household water treatment literature focuses on how best to motivate the individual-level behaviour change required to consistently and correctly use these products. Where individuals are connected to piped supplies, however, automatic system-level chlorination offers clear advantages. There are still maintenance requirements, but that task can be delegated to a small number of community members, rather than to every household. While the lack of appropriate technologies may have limited the usefulness of this approach even a few years ago, more products are available and being further developed for low-maintenance applications. But, as with household products, technical efficacy is only one factor that determines the long-term effectiveness of these safe water solutions. This small study will allow for a better understanding of the factors, such as cost and maintenance requirements, that will determine whether these new system-level passive disinfection approaches may be a strategy to pursue for increasing safe water access in rural communities.

[1] Brown, J., Clasen, T. (2012): High adherence is necessary to realize health gains from water quality interventions. PloS One, *7 (5),* e36735. https://doi.org/10.1371/journal.pone.0036735

[2] Schertenleib, A., Sigrist, J., Friedrich, M. N., Ebi, C., Hammes, F., Marks, S. J. (2019, March 19): Construction of a Low-cost Mobile Incubator for Field and Laboratory Use. J. Vis. Exp. *(145),* Retrieved from: https://bit.ly/2YfZY9M (protocol and video).

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