36th WEDC International Conference, Nakuru, Kenya, 2013

DELIVERING WATER, SANITATION AND HYGIENE SERVICES
IN AN UNCERTAIN ENVIRONMENT

Sachet-type point-of-use (POU) water treatment product comparison for emergencies

J-T. Marois-Fiset & C.C. Dorea, Canada

BRIEFING PAPER 1666

Point-of-use (POU) water treatment and safe storage techniques are effective in improving microbial water quality and decreasing diarrhoeal disease incidence and have potential to be effective interventions in humanitarian emergency contexts. Coagulant/disinfection products (CDPs) can provide microbial quality improvement, turbidity reductions, and a protective post-treatment free chlorine residual. The objective of this study was to compare the treatment performance of 4 commercially-available CDPs with regards to humanitarian water treatment objectives. This is the first comparison of its kind it was demonstrated the (at times significant) inter- and intra-variability of CDP treatment performance between products and with regards to varying water quality, respectively. It is recommended that implementing agencies should conduct field testing for context specific assessments of product performance and acceptability by beneficiaries. Knowledge of product formulation can also help in evaluating its treatment potential.

Introduction

Point-of-use (POU) water treatment and safe storage techniques are effective in improving microbial water quality and decreasing diarrhoeal disease incidence (Clasen et al. 2007). Lantagne and Clasen (2012) have recently pointed towards evidence that POU water treatment techniques can be effective interventions in humanitarian emergency contexts. In such situations, water quality objectives (The Sphere Project 2011) are closely aligned with WHO (2011b) guidelines, namely: no *Escherichia coli* (or thermotolerant coliforms) per 100 mL; turbidity less than 5 nephelometric turbidity units (NTU); and a free chlorine residual (FCR) of 0.5 mg/L.

Of the several available POU water purification techniques, coagulant/disinfection products (CDPs) can provide microbial quality improvement, turbidity reductions, and a protective post-treatment FCR. Most CDPs come in sachets containing a coagulant and a disinfectant along with other (sometimes proprietary) components in powdered form. Typically, these products require 4 steps, specifically: mixing; settling; filtration; and disinfection contact time. Such a treatment approach could be advantageous in relief interventions where the affected population is dispersed (Luff and Dorea 2012) and a centralised water treatment and supply chain is unfeasible. Despite their fixed formulation (i.e. single dose), CDPs are intended to treat waters of variable quality.

The objective of this study was to compare the treatment performance of 4 commercially-available CDPs (Table 1). This assessment was done with regards to the removal of bacterial indicators of faecal origin (e.g. E. coli and thermotolerant coliforms), turbidity reductions, and FCR concentrations (The Sphere Project 2011) as well as the recent quantitative microbial risk assessment (QMRA) based criteria (default values) for the evaluation of POU water treatment options (WHO 2011a).

Table 1. Summary characteristics of tested CDPs.

Product	Form	Coagulant	Disinfectant	Volume treated (L)
A	Powder/sachet (4g)	Ferric sulfate	Ca hypochlorite	10
B	Powder/sachet (2.35)	Ferric sulfate	Ca hypochlorite	10
C	Powder/sachet (2.5g)	Ferric sulfate	Ca hypochlorite	15
D	Powder/sachet (2.5g)	Alum	Ca hypochlorite	20

Materials and methods

The instructions of use of each CDP were adapted to a laboratory setup. A programmable Kemwater Flocculator 2000 (Kemira) stirring paddle was used to provide uniform mixing for the recommended times. The test water matrix consisted of a 20 % dilution of mixing primary settled wastewater in dechlorinated tap water (WHO 2011a) at room temperature; simulating also a grossly polluted untreated water source. Test water turbidity was adjusted to approximately 100 NTU using kaolin. pH was tested at three values (pH 5.0, 7.0, and 9.0). One test (at pH 7) was also run at 5 °C to assess the effects of cold temperatures. A crushed ice jacket around the mixing vessel was used to keep test water at 5 ±1 °C. Keeping in line with the objective of testing the products under challenging conditions, a J-Cloth (Associated Brands, Canada) was used as a filtration material.

Bacterial (i.e. *E. coli* or thermotolerant coliforms) concentrations, turbidity, pH, and FCRs were measured. With the exception of FCR (sampled only after treatment), all other measurements were before and after treatment with the CDPs. Triplicate bacteriological sampling was conducted in sterile bottles containing sodium thiosulfate. Tests for each condition were repeated 3 times. A 24 hour FCR decay test was also conducted in simulated storage conditions in waters of variable chlorine demands (i.e. high, low, and demineralised water).

Results and discussion

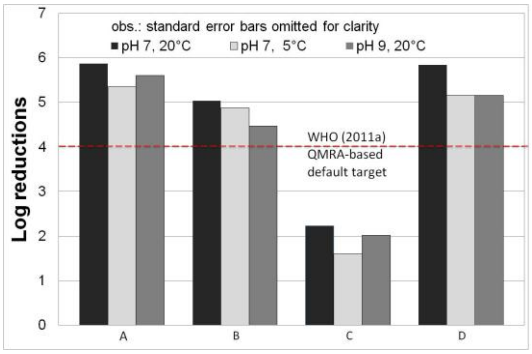

Figure 1. Average bacterial faecal indicator log reductions.

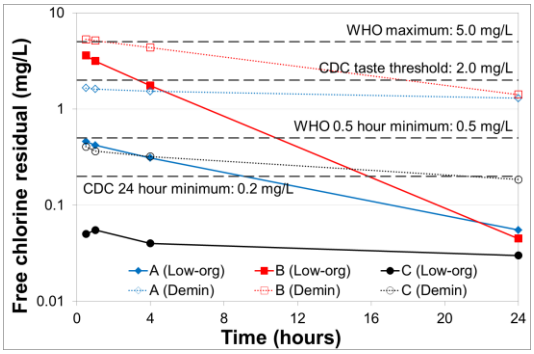

Figure 2. 24 hour FCR decay tests (product D omitted for clarity).

Figure 1 summarises test results (some conditions omitted for clarity). Bacterial faecal indicator log reductions were affected by cold temperatures (CPDs A, B, and C) or alkaline pH (CPDs B, C and D) relative to reference conditions (i.e. pH 7, 20 °C). Such effects can be attributed to reduced coagulation/sedimentation efficiencies and disinfection kinetics (for cold temperatures) as well as the formation of the less effective hypoclorite ions in alkaline conditions (Edzwald 2011). Notably, raw water concentrations were not the same for each product tested with regards to faecal indicator organisms tested. Hence, relatively lower log reductions do not necessarily signify worse final water quality, as maximum removals were observed in many cases with the exception of product C. This was the only one not to achieve the 4 log reduction default target (WHO 2011a) due to its low initial chlorine dose (0.4 mg/L FCR

in demineralised water) and the challenging high chlorine demand of the test water (i.e. diluted primary treatment effluent). It was also the only CDP that failed to consistently produce waters of "low risk" (< 10 cfu/100 mL) or better. In general, CDP C produced treated water considered to be of "high" (i.e. 101 to 1000 cfu/100 mL) or "very high" (i.e. > 1000 cfu/100 mL) risk, depending on the condition tested. All other CDPs could be rated as "highly protective" as per WHO (2011a) criteria (i.e. 4 log removal) with regards to bacterial indicator removals (obs.: viral and protozoan removals were not tested).

24 hour FCR decay tests reveal the variability in disinfectant concentration between products (Figure 2). Also, it is apparent that product B has an accelerated FCR decay, possibly due to its formulation given the standard conditions in which the test was conducted. Such tests also revealed important data with regards to potential acceptability taste issues and capacity to attain 24 hour storage target FCRs. Ideally, FCR residuals should be less than 2 mg/L in order to avoid consumer complaints with regards to chlorinous flavours. This was not achieved with all products (e.g. product B) at the time of treatment. However, it is equally important that minimum residual levels are maintained (0.5 mg/L at 30 minutes and 0.2 mg/L at 24 hours) for their protective action against post-treatment/storage contamination. This is a difficult balance to make and depends on each product's formulation and water quality characteristics (i.e. chlorine demand). In this case, only sodium hypochlorite based products were tested. However, it is possible that NaDCC (i.e. sodium dichloroisocyanurate) based products may offer advantages with regards to maintaining FCRs due to their residual "reservoir" capacity (Clasen and Edmondson 2006).

With CDPs turbidity reduction is a two step process. Some of the particles are removed through the coagulant-assisted sedimentation and particles/flocs remaining in suspension are subsequently filtered through a cloth for further removal. Turbidity reductions were mainly affected by cold temperatures for all products when considering both the settled and finished (filtered) water turbidity. As with chlorination, coagulation and settling are also known to be affected by cold temperatures (Edzwald 2011). Notably, product D performed worse with regards to turbidity removal (even in room temperature experiments). Since such products are designed for a single coagulant dose (for a given volume), its coagulant concentration becomes an important parameter to consider. It is possible that product D has an inadequate alum content. Also, it is worth noting that the cloth material used for filtration was a non-woven viscose fibre fabric chosen to simulate a worst case scenario with regards to choice of filtration material. Thus, a different filtration cloth such as the "thick 100 % cotton" material that is recommended by some products could yield better results. Of the 12 different tests conducted (i.e. 4 products and 3 water quality conditions), only three tests had residual turbidities within recommended limits (< 5 NTU). However, thicker cloths could also lead to longer filtration times. This, in turn, could result in lower adhesion rates in terms of long-term product usage, which could have negative impacts in terms of diarrhoeal disease prevention. Longer treatment times have been previously considered as deterrents to sustained POU product use (Sobsey et al. 2008; Luoto et al. 2011).

Conclusion

This is the first comparison of its kind it was demonstrated the (at times significant) inter- and intra-variability of CDP treatment performance between products and with regards to varying water quality, respectively. It is recommended that implementing agencies should conduct field testing for context specific assessments of product performance and acceptability by beneficiaries. Knowledge of product formulation can also help in evaluating its treatment potential and working range.

Acknowledgements

Support from Oxfam GB and SNC-Lavalin is acknowledged. Names of products were deliberately omitted, but authors may be contacted for further information.

References

Clasen, T. and Edmondson, P. (2006) Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. International Journal of Hygiene and Environmental Health, 209: 173-181.

Clasen, T., Schmidt, W.P., Rabie, T., Roberts, I. and Cairncross S. (2007) *Interventions to improve water quality for preventing diarrhoea: Systematic review and meta-analysis*. British Medical Journal, 334: 782-785.

Edzwald, J. (2011) *Water Quality & Treatment: A Handbook on Drinking Water*, 6th edition. McGraw-Hill Professional, New York, USA.

Lantagne, D. and Clasen, T. (2012) *Point-of-use water treatment in emergency response*. Waterlines, 31(1-2): 30-52.

Luff, R. and Dorea, C.C. (2012) *Bulk Water Treatment Unit performance – for the cameras or the community?* Waterlines, 31(1-2): 53-66.

Luoto, J., Najnin, N., Mahmud, M., Albert, J., Islam, M.S., Luby, S., Unicomb, L., and Levine, D.I. (2011) What Point-of-Use Water Treatment Products Do Consumers Use? Evidence from a Randomized Controlled Trial among the Urban Poor in Bangladesh. PLoS ONE 6(10): e26132.

Sobsey, M.D., Stauber, C.E., Casanova, L.M., Brown, J.M., and Elliott, M.A. (2008). Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. Environmental Science & Technology, 42(12): 4261-4267.

The Sphere Project (2011) *The Sphere Handbook 2011: Humanitarian Charter and Minimum Standards in Humanitarian Response*. Third Edition. Practical Action Publishing. Bourton on Dunsmore, UK.

WHO (2011a) *Evaluating household water treatment options: health-based targets and microbiological performance specifications*. WHO, Geneva, Switzerland.

WHO (2011b) *Guidelines for drinking-water quality*, 4th ed. WHO, Geneva, Switzerland.

Contact details

Jean-Thomas Marois-Fiset
Département de génie civil et de génie des eaux
Université Laval
Québec, QC
Canada G1V 0A6

Caetano C. Dorea
Département de génie civil et de génie des eaux
Université Laval
Québec, QC
Canada G1V 0A6
Tel: +1 418 656 7763
Email: caetanodorea@hotmail.com