Chlorination of hand-dug wells in Monrovia

Régis Garandeau, Andrew Trevett and Andy Bastable

In peri-urban Monrovia, contaminated hand-dug wells were contributing to cholera outbreaks. Various chlorination methods were evaluated to determine their appropriateness and efficacy, both for public health emergencies and sustainable community-managed systems.

By the end of the Liberian conflict in 2003, around 180 000 Internally Displaced Persons (IDPs) had taken refuge in the capital, Monrovia. Substantial damage was caused to much of the water supply and sanitation infrastructure. In peri-urban Monrovia, communities and IDPs mostly drink water from unprotected hand-dug wells, and seriously lack access to basic sanitation. Although cholera is endemic in the area, there was an especially large outbreak in 2003 with more than 17 000 cases. Oxfam GB's emergency response included a programme of hand-dug well protection, construction of VIP latrines, and training of water committees and health promoters in cholera hotspots. Oxfam also experimented with well chlorination techniques both as an emergency measure and to try and establish a sustainable, community-managed chlorination system for traditional and protected wells. This idea was encouraged by the knowledge that some community members already used locally available chlorine to periodically disinfect their wells.[1]

Hand-dug well chlorination

Many factors must be taken into consideration in order to chlorinate a hand-dug well effectively. These diverse factors can be categorized as either quantitative or qualitative. Quantitative factors relate to the volume of water to be treated, which varies according to the abstraction-recovery dynamic. This is further influenced by seasonal demand, location-specific hydrogeology, and rainfall.

The main qualitative factors that affect the chlorination chemistry are pH and temperature. The efficacy of the disinfection process is further influenced by turbidity, which can protect micro-organisms from exposure to chlorine. In addition, chlorine demand will vary according to the presence of faecal contamination, organic matter, iron and manganese. The untreated water quality depends on the well protection, hydrogeology and hygiene practices.

All of these factors are interrelated, variable and virtually impossible to control. However, several low-cost methods are frequently promoted to chlorinate hand-dug wells. Some of these methods are briefly described below.

Pot chlorinators consist of a pierced clay or plastic container. They are filled with layers of chlorine bleaching powder or granules, sand and gravel, and then suspended in the well water (Figure 1). The chlorine slowly disperses into the water, to disinfect it and leave a chlorine residual. The number and size of holes, the type and quantity of chlorine used and the quantity and quality factors previously discussed determine the dose of chlorine released. The main difficulty is to ensure a more or less constant chlorine dose in the well. For example, the first water drawn in the morning may be heavily chlorinated because chlorine continues to dissolve at night when nobody draws water. In contrast, during periods of intensive use, such as early morning, the dose may become too low.[2]

Another approach is to chlorinate wells with liquid bleach. This technique consists of daily injections of bleach in to a well. An approximate chlorine dose is calculated on the basis of well volume and estimated chlorine demand, given the level of contamination. The aim is to leave a constant chlorine residual in the water. Alternatively, bleach is dosed periodically, simply to reduce the level of contamination, which does not guarantee safe water.[3]

Water can also be chlorinated once it has been drawn from the well. Household water treatment with low-strength sodium hypochlorite has been widely promoted. The main challenge with this approach is to ensure its continued use by households, as well as to make it simple and safe, so that people chlorinate their water effectively.

The experimental study

Twelve public wells were selected in three peri-urban communities hosting IDPs that were known to be cholera hotspots. Other selection criteria included the well volume, a mix of protected and unprotected wells, microbiological water quality, and the number of users. A diverse sample was important to better understand how chlorination works in different environments. The sample included three protected wells with hand pumps and nine unprotected wells.

Local shops and markets were visited to determine the availability and prices of materials that could be used to make simple well chlorinators. Chlorine was readily available either as 5% strength liquid bleach or 65% strength calcium hypochlorite granules. It could be found in bulk in the larger shops, and also in

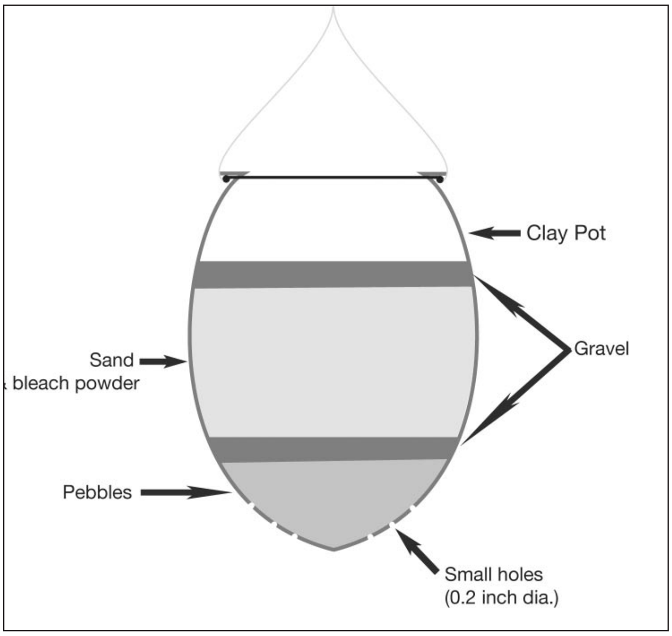

Figure 1 Pot chlorinator in a clay container (after Svadlenka, 2003) [7]

Figure 2 Floating chlorinator [8] (Photo credit: Andy Bastable)

small quantities in peri-urban markets. Materials that could be used to fabricate simple chlorinators, such as cheap plastic containers, plastic bags and rope were also widely available.

Several chlorination technologies were then evaluated over a nine-week study period with the help of community volunteers who monitored Free Residual Chlorine (FRC) at least three times a day using a colour comparator and DPD1 tablets. The evaluation criteria were effectiveness and appropriateness, where effectiveness was defined as FRC remaining between 0.2 and 1.0 mg/litre, even dispersal throughout the well water, and adaptability to different well characteristics. Appropriateness refers to the local availability of materials, easy operation and maintenance, acceptability by communities, cost and logistics issues.

Technologies evaluated

Floating pot chlorinators (Figure 2) and 200 g trichloroisocyanuric acid tablets (chlorine based) were tested in the selected wells. These chlorinators form part of Oxfam's standard equipment for emergencies, though they are normally used in distribution tanks (11 to 70 m^3). The test results showed that FRC values were high but could be adjusted by closing the chlorinator's control valve, and wrapping the chlorine tablets in woven plastic rice bags to slow the rate of chlorine release. However, this chlorinator needed close monitoring and was not easily adaptable to the different wells. Furthermore, the fact that it floats seemed to limit the chlorine dispersion to the water surface. Some well users even expressed annoyance that it got in the way when drawing water. Lastly, although it was found to be fairly effective and appropriate, this technology is imported and is therefore less sustainable than local alternatives.

Simple pot chlorinators were made from recycled 4-litre local bleach jerrycans (Figure 3). They were filled with layers of gravel, sand and locally available calcium hypochlorite granules, and then tested in the wells. These designs were judged to be quite appropriate, but relatively ineffective, as the chlorine granules dissolved too quickly, resulting in FRC values of up to 10 mg/litre.

Well chlorination with liquid bleach was also evaluated. Because of the ongoing risk of cholera outbreaks, only methods aimed at leaving a constant chlorine residual in the wells were tested. This was achieved by dosing wells with 5% bleach injections twice per day. The initial dose was calculated on the basis of the well's volume and an estimated chlorine demand to leave a 1.0 mg/litre residual. Subsequent doses were adjusted using the well volume and FRC level. Doses were measured with a syringe and ranged from 30 to 110 mg/litre. The chlorine dose was added to the well, and then several buckets of water were drawn and poured back in, to facilitate mixing. The wells were then closed for 30 minutes. This proved fairly effective and appropriate but FRC levels did not remain above 0.2 mg/litre all day in all wells. Similar results were observed in a study from Guinea Bissau.[4] Moreover, this technique was considered a burden because of the dosing regime (twice daily), and it required careful training.

Although not field tested in the Monrovia wells, household chlorination was also evaluated using the wells' chlorine demand data. Local bleach can

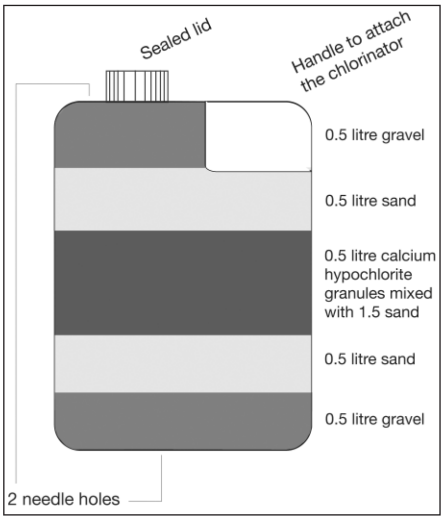

Figure 3 Locally made pot chlorinator

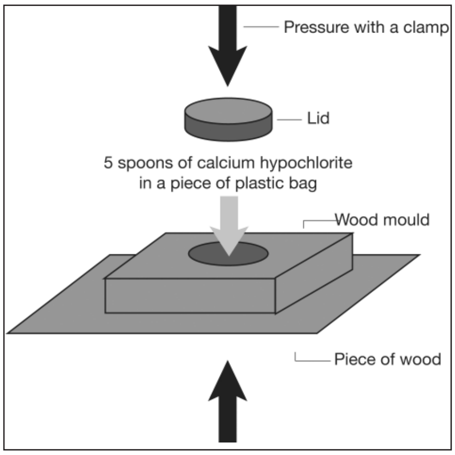

Figure 4 Locally manufactured press for calcium hypochlorite tablets

be measured in drops or millilitres with a syringe, but the difficulty is to provide households with simple chlorination guidelines to avoid under-dosing (ineffective) or overdosing (dangerous and counterproductive).[5] Prior to any chlorination, the wells' chlorine demand values ranged from 0.2 to more than 6 mg/litre. In such conditions, standard guidelines e.g. x ml in y litres would inevitably be of little use, even with a long contact time.

Previous work by Action Contre la Faim in Ethiopia had reported a well chlorination technique that used locally pressed chlorine tablets.[6] It was decided to try and replicate this approach in Monrovia. A simple manual press was designed and made from wood to produce tablets of calcium hypochlorite of approximately 70 g (Figure 4). One or two of these tablets were placed in strong plastic bags filled with 2 litres of sand, pierced twice with a needle, tied with a rope and then suspended in the wells (Figure 5). This method was found to be both very effective and appropriate. FRC levels remained in the desired range of 0.2 to 1.0 mg/litre in all wells for between 3 to 6 days. All materials were locally available and cheap. This system was easy to operate and maintain and well accepted by the well users. The chlorinator was suspended as near as possible to the midpoint between the water surface and well bottom to ensure even chlorine dispersion.

Contact time, however, remains problematic with all chlorination methods. The rate of chlorine dispersion varies to some extent according to the chlorinator design, with more rapid dispersion meaning that contact time is minimized. However, unless the well is closed or users respect the minimum contact time, the health benefit of chlorination is undermined.

The importance of training and hygiene promotion

The people responsible for chlorination should be well trained, as chlorine can be dangerous. Furthermore, users need to know which wells are chlorinated and why. Contact time needs to be carefully explained, and it might be necessary to ask people to wait 30 minutes between drawing water and drinking it. Even with an adequate chlorine residual and minimum contact time, hygiene practices concerning safe water abstraction, transport and storage should also be promoted.

Summary

Well chlorination using locally pressed calcium hypochlorite tablets in pierced plastic bags filled with sand, together with adequate training, awareness raising and hygiene promotion can be an effective way of fighting waterborne diseases.

As this chlorination system is simple, quick and cheap, it can be used in short-term emergencies. However, chlorination is not a long-term substitute for the protection of wells, which is more sustainable than chlorination on its own. Ideally, well protection and chlorination should be used jointly to ensure a safe water supply for communities and to protect against recontamination during storage.

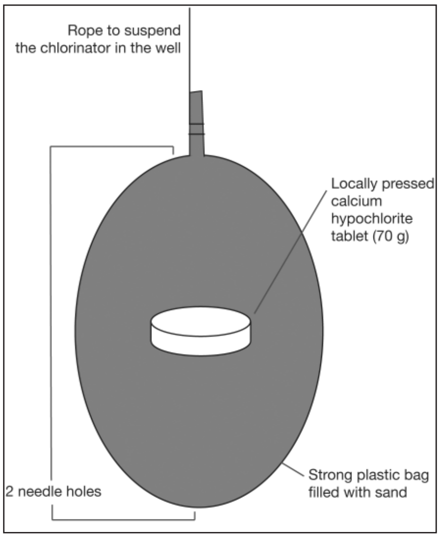

Figure 5 Pot chlorinator with a pressed calcium hypochlorite tablet.

Acknowledgements

This research was carried out for Oxfam GB in Liberia. The opinions in this work are those of the authors and do not necessarily represent Oxfam policy. The support and advice provided by Daudi Bikaba and Zulfiquar Ali Haider of Oxfam GB was much appreciated.

About the authors

Régis Garandeau is a Public Health Engineer for Oxfam GB. Andrew Trevett is a Lecturer in Community Water Supply at Cranfield University. Andy Bastable is Senior Public Health Engineering Adviser for Oxfam GB.

References

1 Garandeau, R. (2004), *Chlorination for hand-dug wells in peri-urban Monrovia*, MSc thesis, Cranfield University: Silsoe.
2 IFRC (2004), *The Johns Hopkins and IFRC Public Health guide for emergencies*, Chapter 5 Environmental Health. http://www.ifrc.org/docs/pubs/health/chapter 5.pdf
3 Godfrey, S. (2003), *Appropriate chlorination techniques for wells in Angola*, Waterlines, vol. 21 No. 4, pp. 6–8. ITDG Publishing: London.
4 Rowe, K. A. et al (1998), *Chlorinating well water with liquid bleach was not an effective water disinfection strategy in Guinea-Bissau*, International Journal of Environmental Health Research, vol. 8 No. 4, pp. 339–340. Taylor and Francis: London.
5 UNICEF Liberia (undated), *How to make your water safe to drink, UNICEF household chlorination instructions*. UNICEF Liberia: Monrovia.
6 Libessart, Y., Hammache, Y. (2000), *Integrated chlorination campaign in Mogadishu*, Proceedings of the 26th WEDC Conference in Dhaka, Bangladesh, pp. 237–239. WEDC: Loughborough.
7 Svadlenka, M. R. (2003) *Improving local water supply in rural communities: Challenges, techniques, and opportunities,* http://www.worldhungeryear.org/why_speaks/ws_load.asp?file=19&style=ws_table
8 Pool Supplies (2004), *Floating pot chlorinator*, http://www.poolsupplies.com/graphics/newproducts/108077.jpg