Viability of Commercially Available Bleach for Water Treatment in Developing Countries

Daniele S. Lantagne, MEng

Treating household water with low-cost, widely available commercial bleach is recommended by some organizations to improve water quality and reduce disease in developing countries. I analyzed the chlorine concentration of 32 bleaches from 12 developing countries; the average error between advertised and measured concentration was 35% (range=–45%–100%; standard deviation=40%). Because of disparities between advertised and actual concentration, the use of commercial bleach for water treatment in developing countries is not recommended without ongoing quality control testing. (Am J Public Health. 2009;99:1975–1978. doi: 10.2105/AJPH.2009.160077)

An estimated 1.1 billion people lack access to improved water supplies and 2.6 billion people are without adequate sanitation.1 The health consequences of inadequate water and sanitation services include an estimated 4 billion cases of diarrhea and 1.6 million deaths each year, mostly among young children in developing countries.2,3

Chlorination was first used for disinfection of public water supplies in the early 1900s and is 1 factor that has contributed to dramatic reductions in waterborne disease in US cities.4 Large-scale trials of point-of-use chlorination began in the 1990s as part of the Pan American Health Organization and the US Centers for Disease Control and Prevention (CDC) response to epidemic cholera in Latin America.5 The CDC/Pan American Health Organization Safe Water System strategy includes 3 elements: (1) water treatment with dilute sodium hypochlorite at the point of use; (2) storage of chlorinated water in a safe container, and (3) behavior change communication to improve hygiene and water and food-handling practices. In 6 randomized, controlled trials, use of the Safe Water System strategy resulted in reductions in diarrheal disease incidence ranging from 26% to 84%.6–11

The CDC and the social marketing non-governmental organization Population Services International (PSI) have partnered in 19 countries to locally produce and market a Safe Water System chlorination product (Figure 1). The sodium hypochlorite solution is packaged in a 150 mL bottle with directions instructing users to add 1 full bottle cap of the solution to clear water (or 2 caps to turbid water) in a standard-sized 20-L storage container, agitate, and wait 30 minutes before drinking. The average consumer cost of the PSI products available in 16 countries in 2007, which each treats 1000 L, was US$0.328, with a range from US$0.148 to US$0.968. If the highest-cost outlier of Cameroon is removed, the average cost was US$0.285, with a range from US$0.148 to US$0.491.

Program implementers have inquired whether commercially available sodium hypochlorite bleaches can be used for Safe Water System programs. The concentration of locally available commercial bleaches (3% to 6%) is higher than that of PSI Safe Water System products (approximately 1.25%), and commercial bleach is generally less expensive. It has been suggested that the PSI products treat less water at a higher cost than locally available commercial bleaches.

However, factors other than cost by volume and advertised percentage hypochlorite need to be considered when one compares commercial bleaches and the Safe Water System products. Initial Safe Water System programs opted to develop a lower-concentration, specially branded product for several reasons, including (1) consumer reluctance to use commercial bleach for water treatment because of strong smell and associations with cleaning, (2) variable hypochlorite concentration in commercial bleach observed in quality control testing, (3) potential presence of fragrances and additives in commercial bleach that may be unsafe for human consumption, (4) higher stability of sodium hypochlorite solution at lower concentrations, and (5) ease of dosing at lower concentrations (1 cap) compared with higher concentrations (20 drops of commercial bleach for treating 20 L) (E.D. Mintz and R. Quick, oral communication, June 2008).

To develop an accurate Safe Water System dosage regime,12 the concentration of the bleach used as the sodium hypochlorite donor must be known within 10% error. Many factors can negatively impact the quality of bleach and reduce the expiry time, including higher concentration hypochlorite solution, contaminated dilution water, exposure to metal ions during the manufacturing process, inappropriate packaging, exposure to heat and light during transport and storage, and lack of proper pH stabilization to pH values of 11 to 13 (K. Vieira, Clorox Services Company, oral communication, 2007).13,14 Socially marketed Safe Water System products are manufactured with stringent production standards and quality control procedures to ensure quality control during product life.15 Commercially available bleaches are not always manufactured to these standards, and this research was conducted to determine whether lower-cost bleaches might be of high enough quality to recommend for ongoing household water treatment in developing countries.

METHODS

As part of routine technical assistance trips during 2004 to 2007, I analyzed commercial bleaches for sodium hypochlorite concentration and pH. I measured sodium hypochlorite concentration with a Hach Method 8209 portable iodimetric titration kit for high-range (20 mg/L–70,000 mg/L) total chlorine (Hach Co, Loveland, CO). I measured pH with a Hanna Instruments multimeter (Hanna Instruments, Bedfordshire, UK) calibrated weekly with nonexpired stock calibration solutions. I entered data into Excel X for Mac, 2001 version (Microsoft Corp, Redmond, WA) and analyzed the data with the Microsoft Excel Analysis ToolPak.

I tested 32 bottles of commercially available bleach in 12 different countries between March 2004 and March 2007 (Table 1). Fourteen (44%) of the 32 bottles were imported, with the remaining 18 (56%) produced locally. Some countries, such as...
Angola, have multiple independent bleach producers, which were the source of 100% of the 5 samples found in that country. Other countries, such as Burundi, import bleach from Europe (Belgium and France) and from neighboring Kenya. The retail price and volume of the commercial bleach bottle were available for 21 (66%) of the 32 products tested. The mean cost per 150 mL (the volume equivalent to the PSI Safe Water System product) was US$0.32 (range=US$0.06– US$3.00). When the outlier (US$3.00) was excluded, the mean cost per 150 mL fell to US$0.18 (range=US$0.05–US$0.38). Commercial bleaches were less expensive, by volume, than Safe Water System products. In addition, 150 mL of higher-concentration bleach will treat a proportionally greater volume of water than the 1.25% solution PSI product.

Only 24 (75%) of the 32 commercial bleaches advertised a concentration on the packaging (Table 2). The average advertised concentration was 4.9% (range=1.0–9.6). The mean measured concentration of the 32 commercial bleaches was 2.9% (range=0.0–6.1; Table 2). Ten of the 32 sodium hypochlorite samples (31%) were duplicated for quality control. The mean relative percent difference between initial and duplicate samples was 1.61% (range =0.16–4.9). The pH of the commercial bleaches varied from 8.9 to 12.4, with a mean of 11.6. Only 1 sample was not stabilized to a minimum pH of 11.0.

### RESULTS

The average error between advertised and measured concentration was 35% (range=−45%–100%; standard deviation =40%; Table 2). A negative error indicates measured concentration was higher than advertised concentration. The difference between advertised and measured concentrations in the 24 commercial bleaches with advertised concentrations was significant with a paired t test ($P<.001$). The results remained significant when subdivided to include only imported bleaches ($P=.0057$) or only locally produced bleaches ($P=.02$). Only 6 (25%) of the 24 bottles with advertised concentrations were within the required 10% accuracy required as the acceptable range for use in Safe Water System dosing. These bottles were from Kenya (n=3), Yemen (n=1), Ethiopia (n=1), and Guyana (n=1).

### DISCUSSION

On the basis of the variability seen in 32 commercial bleach samples from 12 countries, the use of commercial bleaches for household water treatment in developing countries cannot be widely recommended. Without a consistent and standardized product, it is not possible to develop an accurate, dependable dosage regime. Although the cost of commercial bleaches is less than the cost of PSI products, the quality of commercial bleaches is insufficient for use in Safe Water System programs.

### TABLE 1—Commercial Bleach Bottles Tested, by Country, Importation Status, Cost, and Volume: 2004–2007

<table>
<thead>
<tr>
<th>Country</th>
<th>Bottles Tested, No.</th>
<th>Bottles Imported, No. (%)</th>
<th>Bottles With Cost and Volume Available, No. (%)</th>
<th>Cost (US$) for 150 mL Average Volume (Min, Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>5</td>
<td>0 (0)</td>
<td>3 (60)</td>
<td>0.16 (0.13, 0.20)</td>
</tr>
<tr>
<td>Burundi</td>
<td>3</td>
<td>3 (100)</td>
<td>1 (33)</td>
<td>3.00</td>
</tr>
<tr>
<td>Cameroon</td>
<td>1</td>
<td>1 (100)</td>
<td>1 (100)</td>
<td>0.30</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>5</td>
<td>1 (20)</td>
<td>1 (20)</td>
<td>0.21</td>
</tr>
<tr>
<td>Guinea</td>
<td>1</td>
<td>1 (100)</td>
<td>1 (100)</td>
<td>0.34</td>
</tr>
<tr>
<td>Guyana</td>
<td>1</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0.20</td>
</tr>
<tr>
<td>Kenya</td>
<td>5</td>
<td>1 (20)</td>
<td>5 (100)</td>
<td>0.14 (0.06, 0.20)</td>
</tr>
<tr>
<td>Mozambique</td>
<td>1</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0.15</td>
</tr>
<tr>
<td>Nepal</td>
<td>1</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>. . .</td>
</tr>
<tr>
<td>Niger</td>
<td>2</td>
<td>2 (100)</td>
<td>1 (50)</td>
<td>0.16</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>. . .</td>
</tr>
<tr>
<td>Yemen</td>
<td>6</td>
<td>4 (67)</td>
<td>6 (100)</td>
<td>0.18 (0.10, 0.37)</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>14 (44)</td>
<td>21 (66)</td>
<td>0.32 (0.06, 3.00)</td>
</tr>
<tr>
<td>Total*</td>
<td>31</td>
<td>13 (42)</td>
<td>20 (65)</td>
<td>0.18 (0.06, 0.38)</td>
</tr>
</tbody>
</table>

*Excluding high-cost Burundi outlier of US$3.00 for 150 mL.
Potential reasons for the high variability seen in commercial bleaches in developing countries include use of contaminated dilution water and exposure to metal ions during the manufacturing process, inappropriate packaging in low-density polyethylene or transparent bottles, insufficient quality control in manufacturing, and degradation caused by heat and light exposure during transport and storage. This degradation was seen despite almost universal pH stabilization.

Commercially available bleaches could be used for water treatment in developing countries if a dosage regime is developed by (1) testing each batch of commercial bleach for sodium hypochlorite concentration and calculating the appropriate dose for that batch; or (2) following the World Health Organization’s guidelines for emergency water treatment, and adding known quantities of each batch of commercial bleach to source waters until the correct residual is found. Both methods require trained operators who can perform ongoing water quality testing, and can potentially lead to a different dosage regime for each batch of commercial product.

Other chlorine options for developing country Safe Water System programs include (1) locally made PSI Safe Water System products in 19 countries; (2) sodium dichloroisocyanurate tablets imported from manufacturers in developed countries; (3) sodium hypochlorite solution generated locally by using a commercially available hypochlorite generator and salt, water, and electricity; and (4) high-quality sodium hypochlorite manufactured by reputable local producers. The appropriate chlorine option depends on the capacity, financial constraints, and program strategy of the implementing organization.

Results from this investigation are not applicable to the use of commercial bleach for emergency water treatment in disasters in developed countries. Adequate product labeling, high production quality, quality-control measures, and fast-moving distribution chains in developed countries prevent many of the factors associated with degradation of bleach seen in developing countries.

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Human Participant Protection
No institutional review board approval was required as no human participants were involved in this research.

References

About the Author
Daniele S Lantagne is with the Centers for Disease Control and Prevention, Atlanta, GA.
Correspondence should be sent to Daniele Lantagne, PE, 1600 Clifton Rd, MS-A38, Atlanta, GA, 30333 (e-mail: dlantagne@cdc.gov). Reprints can be ordered at http://www.aphid.org by clicking the “Reprints/Eprints” link. This brief was accepted February 14, 2009.

STD Prevalence, Risky Sexual Behaviors, and Sex With Women in a National Sample of Chinese Men Who Have Sex With Men

We describe the behavioral characteristics and sexually transmitted disease (STD) prevalence of Chinese men who have sex with men (MSM) (n = 41) from a national probability sample of men (n = 1861). Most MSM were partnered with females (97%) and had a low rate of consistent condom use (7%). More MSM than heterosexual men self-reported a prior STD and risky sexual behaviors. MSM may act as a bridge for HIV transmission to female partners. Targeted interventions may help prevent a generalized HIV epidemic in China. (Am J Public Health. 2009;99:1978–1981. doi: 10.2105/AJPH.2008.150037)

In some parts of China, HIV prevalence has exceeded 1% of the general population. Men who have sex with men (MSM) accounted for 7.3% of HIV infections and 11% of new HIV infections in 2007. The proportion of HIV infections among MSM is likely to grow, as studies have documented increasing HIV prevalence and high prevalence of risky sexual behaviors and of sexually transmitted diseases (STDs) among this population.

STDs may serve as a bridge population for transmitting HIV to the general population. Empirical data have shown that a large proportion of Chinese MSM are either married or have female sex partners. High-risk sexual behaviors with both male and female partners among MSM are also common. Surveys have documented extremely high rates of inconsistent condom use with female partners.

We report the sociodemographic and sexual behavioral characteristics and the STD prevalence of a national probability sample of Chinese heterosexual men and men who had homosexual experiences.

METHODS

A Chinese household survey (not including Hong Kong and Tibet) of adults aged 20 to 64 years was implemented between 1999 and 2000 with probabilistic sampling, as part of the Chinese Health and Family Life Survey. The procedures in this study were previously reported in detail elsewhere. Of the 5000 individuals sampled nationally, 3813 completed the computerized interview and 3426 (participation rate = 69%) also provided a urine sample.

Adult MSM (n = 41) and heterosexual men (n = 1820) were identified through participants’ reply to the question, “Have you ever had sex with another man?” Sociodemographic characteristics, including place of residence, education, employment, marital status, and monthly income, were also recorded. Condom use with spouse or primary sex partner, sexual encounters with nonprimary partners, and whether participants ever gave or received money, gifts, or valuables for sex were assessed. Finally, participants self-reported lifetime history of any STD. Urine specimens were collected and tested for gonorrhea and chlamydia by standard laboratory methods.

RESULTS

Of 1861 male participants who answered the question concerning MSM behavior, 41 (2.2%) reported ever having had sex with men (Table 1). MSM appeared to be younger than heterosexuals (42% vs 27% were younger than 30 years old), although the difference was statistically nonsignificant. A majority of MSM (85%) did not attend any form of college, but they were significantly more likely than were heterosexual men to have attained more than a primary school education (98% vs 84%; P = .041). Heterosexual men were more likely to be married than were MSM (85% vs 68%; P = .027), but it is important to recognize that most MSM were currently married.

Sex with Women and Risky Sexual Behaviors

Of the 34 MSM who reported having a spouse or primary sex partner (hereafter called “partner”), the partner was female in all but