Evaluating in-home water purification methods for communities in Texas on the border with Mexico

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ABSTRACT *This study evaluated user preferences among three alternative in-home water treatment technologies suitable for households relying on trucked water in El Paso County, Texas, which is on the border with Mexico. The three technologies were: chlorination of household storage tanks, small-scale batch chlorination, and point-of-use ultraviolet disinfection. Fifteen households used each of the three technologies in succession for roughly four weeks each during April through June of 2004. Data were collected on treated water quality, and a face-valid survey was administered orally to assess user satisfaction with the technologies on a variety of attributes. Treatment with a counter-top ultraviolet disinfection system received statistically significantly higher ratings for taste and odor and likelihood of future use than the other two approaches. Ultraviolet disinfection and small-scale batch chlorination both received significantly higher ratings for ease of use than did storage tank chlorination. Over-chlorination was a common problem with both batch chlorination and storage tank chlorination. Water quality in the households using trucked water is now higher than was reported by a previous study, suggesting that water quality has improved over time.*

Key words Water supply, water purification, consumer satisfaction, Texas, United States.

Many households in the United States-Mexico border region cannot realistically expect to be connected to a public drinking water supply in the near future. In El Paso County, Texas, 3 460 residents lack a piped water supply, and extending water supply lines to them would cost an average of US$120 000 per household (1). Directly across the border in Ciudad Juárez, Mexico, 4.7% of the population, or 57 000 individuals, lack access to a piped water supply (2). These households often rely on water delivered by trucks, stored in 2 500-gallon tanks, and pumped to a pressurized indoor plumbing system. In a study of El Paso County residents using trucked water, Graham and Vanderslice (3) reported that the water in these systems was frequently contaminated during transport and storage. After 9 months of follow-up, 97% had < 0.5 mg/L chlorine residual (Texas requires water haulers to maintain a residual of 0.5 mg/L, but this may decay after delivery), 80% tested positive (≥ 1 CFU/100 mL) for total coliform bacteria (an indicator of environmental influence but not necessarily of fecal contamination), and 3% tested positive for *E. coli*. Because of water quality concerns, many families rely on vended or bottled water for potable use. In-home treatment may be a less expensive means to ensure water quality. While

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the effectiveness of several in-home treatment technologies has been established (4), comparative studies are rare, and there is little information on which methods would be most appropriate for this setting. This study compared three in-home water treatment strategies for these communities to assess which technologies the participants preferred and used most effectively. The technologies evaluated were: (1) storage tank chlorination, in which residents check the chlorine levels in their 2 500-gallon storage tank at periodic intervals and adjust as necessary; (2) small-scale batch chlorination, in which households take 5-gallon portions of water, add chlorine bleach for disinfection, and store the water in a covered container with a tap; and (3) counter-top ultraviolet (UV) disinfection, in which a commercially available (Puritec, Las Vegas, Nevada, United States) UV counter-top unit costing roughly US$ 100.00 was installed by participants using an adaptor to their kitchen tap. The price reflects a discount for purchasing in bulk; current retail costs are US$ 189.00/unit, and annual replacement of the pre-filter and lamp costs roughly US$ 64.00/year. Costs for the first two treatment options are minor (< US$ 10.00/year).

With approval from the Institutional Review Board of the University of Texas at El Paso, the study was conducted from April through July of 2004 in the Dairyland and College Park neighborhoods of El Paso County. A quasi-experimental study design was employed in which each of the households tried each of the three treatment methods for four weeks. Participants were recruited through a local community-based organization, which may lead to a more compliant population than would be expected generally but is not expected to influence the relative ratings of the three different technologies. Most of the participants were female, as women were home during the afternoon site visits. Participants reported on the taste of the treated water but were not required to use the treated water exclusively. For logistical reasons, technologies were evaluated in the following order for all households: tank chlorination, small-scale batch chlorination, and counter-top UV treatment. Participants were trained in the use of each treatment method at an educational session. Bilingual researchers visited each household to collect water samples and administer a questionnaire a total of seven times, with an initial baseline visit and two visits for each of the three treatment technologies (one two weeks and one four weeks after the introduction of the technology). The questionnaire was reviewed by study researchers and deemed face-valid. To attempt to mitigate recall biases, participants were asked the same questions after similar durations of use of each technology. A few comparative questions were asked on the final survey, and for these questions, recall bias may have made the characteristics of the last technology considered (UV treatment) more salient (5). Water samples were analyzed for residual chlorine using a HACH (Loveland, Colorado, United States) field kit, and total coliform bacteria and *E. coli* using the IDEXX Colilert method (Westbrook, Maine, United States). Water was allowed to run from the faucets for 30 seconds prior to the collection of samples to avoid contamination from the tap. Of the 20 households initially recruited, a total of 5 were lost to follow-up, 3 after the initial baseline visit, 1 after completing the evaluation of tank chlorination, and 1 after completing the evaluation of batch chlorination. The overall 75% retention rate appears reasonable for a study that was both lengthy and demanding for its participants. SPSS software (Chicago, Illinois, United States) was used to calculate P values for statistical tests, and values below 0.05 were considered statistically significant.

Participants evaluated the technologies for ease of use, perceived safety of the treated water, taste and odor, and likelihood of future use on a 7-point Likert scale. On comparing survey results for the second visit of each of the three technologies, we found that UV disinfection received significantly more favorable ratings (an average of 1.9 on a scale from –3 to 3) for the taste and odor of the treated water, compared to 0.6 for tank chlorination and –0.1 for batch chlorination ($P = 0.047$ and $P < 0.01$ for paired t tests of UV disinfection with tank chlorination and batch chlorination, respectively), and the likelihood of future use ($P = 0.02$ and $P < 0.01$ for paired t tests of UV disinfection with tank chlorination and batch chlorination, respectively). Tank chlorination was rated less favorably on ease of use (average rating of 0.5) than UV (average rating of 2.1 for UV disinfection was significantly different from tank chlorination, at $P < 0.01$) and batch chlorination (average rating of 1.7 for batch chlorination was significantly different from tank chlorination, at $P = 0.02$), but there was no significant difference between UV disinfection and batch chlorination on this attribute. All three treatment methods received similar and relatively high ratings for safety of treated water (2.1 for tank chlorination, 1.5 for batch chlorination, and 2.0 for UV disinfection), which agrees with technical views that, when applied properly, UV treatment and chlorination can safely disinfect water.

Comparing the attribute ratings at the first and second visits for each of the three technologies yielded a total of 12 comparisons. In 10 cases the attributes did not differ significantly between the first and second visit. The ease of use of batch chlorination rose significantly (from 0.3 to 1.7, significantly different at $P < 0.01$) between the first and second visits, presumably as participants became more comfortable with the process over time. In contrast, the likelihood of future use of tank chlorination declined over time (from 2.2 to 1.5, significant at $P = 0.03$), possibly as participants became more aware of the difficulties of monitoring chlorine and gaining access to their tanks, which generally requires a ladder. The source of water used by participants changed over the course of the study. At the start of the study none of the participants drank the water from their tanks, instead relying on bottled water,

vended water, etc. At the conclusion of the study, 57% of the participants used the UV-treated water as their drinking water source, and indicated that they would continue to do so in the future.

A majority of the participants were not willing or able to use storage tank chlorination even on a trial basis. Only 41% of the households reported that they carried out storage tank chlorination during the four-week evaluation period for this technology, compared to 100% that used small-scale chlorination and UV countertop treatment during their respective four-week evaluation periods (significant at $P < 0.01$). Most residents found it too difficult to climb onto the storage tanks to measure and adjust chlorine levels. Although this technology has been recommended by previous outreach efforts, it does not appear suitable for widespread use.

Taste and odor concerns may be inherent to the use of chlorine disinfection, but were probably exacerbated by a tendency to add more than the recommended dose of chlorine. The chlorination instructions were designed to produce a chlorine residual of 1–2 mg/L. Chlorine residuals > 2 mg/L were classified as "elevated" (because most households with elevated chlorine had > 3 mg/L, the exact threshold is not important). Although residual chlorine levels up to 4 mg/L are legal, high chlorine levels are unpalatable and may result in dissatisfaction with the treated water. None of the households had elevated chlorine levels at the baseline visit; however, a substantial proportion of the households had elevated chlorine levels when the two chlorination treatment methods were used. On the first visit for tank chlorination, 45% had high chlorine residual, a significantly higher percentage than the baseline value of 0% ($P < 0.01$ for a test of two proportions), and 19% did on the second visit. For small-scale chlorination, 38% had elevated chlorine on the first visit, a percentage significantly higher ($P < 0.01$) than at baseline, and 25% did on the second visit. Although over-chlorination is known to be a potential problem (4), quantitative assessments of residual levels are not common and merit more attention in future studies.

The residents lacked confidence in the safety of the hauled water, as evidenced by the fact that none of the households used this water for drinking without subsequent treatment, relying instead on bottled water, vended water, etc. Whether the water presented any substantial risk is less clear. At the baseline visit, storage tanks samples from 20% of the households had < 0.5 mg/L chlorine residual, 10% tested positive (≥ 1 CFU/100 mL) for total coliform bacteria, and no samples tested positive (≥ 1 CFU/100 mL) for *E. coli*. The absence of *E. coli* indicates that much of the bacteriological growth was not from sewage contamination, but the presence of an inadequate chlorine residual in 20% of the homes suggests that water quality is still a concern. Graham and Vanderslice (3), using data collected in 1999, found much poorer trucked-water quality (see above for a summary), which suggests that the water quality may have improved by the time this study was conducted in 2004.

The appropriate technology for in-home water treatment may depend on a variety of regional factors, such as source water quality, and even household-specific factors, such as income. Although this study is limited in size and duration of follow-up, the results tend to support the use of UV disinfection as a household water treatment, whereas chlorination or other technologies may be appropriate for households that lack plumbing systems or for which the cost of the unit would be an economic hardship. Although this study suggests that in-home water treatment methods can gain acceptance by users, it also found that impressions can change at least somewhat over time, indicating that longer-term follow-up is necessary to assess participants' willingness to use and adequately maintain the devices over time.

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REFERENCES

1. Crowder D. Study shows 3,460 have no waterlines. El Paso Times (Section B, Borderland) 2003. February 26:2.
2. Mexico, Instituto Nacional de Estadística, Geografía e Informática. Indicadores seleccionados de vivienda por municipio, 2000. Available from: http://www.inegi.gob.mx/est/contenidos/espanol/rutinas/ept.asp?t=mviv22&c=4236&e=08. Accessed 8 January 2006.
3. Graham J, Vanderslice J. The effectiveness of large household water storage tanks for protecting the quality of water. J Water Health. Forthcoming 2007.
4. Sobsey M. Managing water quality in the home: accelerated health gains from improved water supply. Geneva: World Health Organization; 2002.
5. Plous S. The psychology of judgment and decision making. New York: McGraw-Hill; 1993.

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RESUMEN

Evaluación de métodos domésticos de purificación de agua para comunidades de Texas fronterizas con México

Este estudio evaluó las preferencias de los consumidores de tres tecnologías domésticas para el tratamiento del agua, apropiadas para viviendas del condado de El Paso, Texas, situado en la frontera con México, que dependen del agua transportada en camiones. Las tres tecnologías fueron cloración de los tanques domésticos de almacenamiento, cloración de pequeños lotes de agua y desinfección mediante luz ultravioleta en el punto de dispensación. Quince viviendas utilizaron sucesivamente cada una de las tres tecnologías durante aproximadamente cuatro semanas entre abril y junio de 2004. Se registraron los datos sobre la calidad del agua tratada y se realizó una encuesta oral aceptada por los expertos para medir el grado de satisfacción de los usuarios con relación a diversos atributos de esas tecnologías. El tratamiento con el sistema de desinfección mediante luz ultravioleta instalado sobre la barra de la cocina tuvo una mejor valoración según el gusto y el olor del agua y una mayor probabilidad de uso futuro que los otros dos métodos. La desinfección mediante luz ultravioleta y la cloración de pequeños lotes recibieron mayor puntuación por su facilidad de uso con respecto a la cloración de los tanques de almacenamiento. La cloración excesiva fue un problema frecuente, tanto en la cloración de pequeños lotes como de los tanques de almacenamiento. La calidad del agua en las viviendas que utilizan agua transportada en camiones es ahora superior que la encontrada en estudios anteriores, lo que parece indicar que la calidad del agua ha mejorado.

Palabras clave Abastecimiento de agua, purificación del agua, satisfacción de los consumidores, Texas, Estados Unidos.