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Difficulties in Bringing Point-of-Use Water Treatment to Scale in Rural Guatemala

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Abstract. In an earlier study in rural Guatemala, 257 households that received flocculant-disinfectant to treat their drinking water had 39% less diarrhea than 257 control households. Three weeks after completion of the study, national marketing of the flocculant-disinfectant was extended into the study communities. Six months later, we assessed frequency of and characteristics associated with purchase and use of the flocculant-disinfectant by revisiting the original study households and administering a questionnaire. Four hundred sixty-two households (90%) completed the follow-up survey; 22 households (5%) purchased the flocculant-disinfectant within the preceding 2 weeks and used it within the last week. Neither being randomized to the intervention group during the efficacy study nor combined spending on laundry soap, toothpaste, and hand soap in the preceding week was associated with active repeat use. Even after efficacy was demonstrated within their community and an aggressive sophisticated marketing approach, few households purchased flocculant-disinfectant for point-of-use water treatment.

INTRODUCTION

The World Health Organization (WHO) estimates that 1.1 billion people lack access to an improved water supply.[1] Even if the ambitious millennium development goal of reducing by half the proportion of people without sustainable access to safe drinking water is achieved, several hundred million people will still be dependent on an unimproved drinking water supply in 2015. Historically, extending improved water infrastructure to low-income households has proven difficult. Between 1990 and 2000, although the proportion of households with an improved water supply increased, the number of persons without improved water remained unchanged because of the continued growth of impoverished populations.[1] Moreover, many water supplies that meet the WHO definition of improved are frequently heavily contaminated with human fecal organisms.[2–5] Thus, the number of persons exposed to microbiologically unsafe water far exceeds 1.1 billion. This contaminated water contributes importantly to the estimated 2 million persons who die of diarrhea and typhoid fever each year.[6–8]

One approach to bring more rapid improvement to households with microbiologically unsafe drinking water is to treat water at the point of use. Various technical approaches have been deployed including chemical treatment, solar irradiation, filtration, and combined approaches.[9,10] Numerous small-scale efficacy studies have evaluated point-of-use water treatment. Such studies consistently show that, in settings where diarrhea is a leading cause of death, persons who live in households that regularly treat their drinking water with an approach that is microbiologically effective have less diarrhea than persons living in households that do not treat their drinking water at the point of use.[11] Indeed, the strength of the evidence has led WHO to conclude that point-of-use water treatment is the most cost-effective approach to reach the millennium development goal of halving the number of persons with no access to safe water.[12]

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However, efficacy studies are artificial experiments. Typically, study participants are given water treatment supplies at no cost and are aggressively encouraged to use them. Limited data are available on household water treatment outside of efficacy studies. One exception is an independent evaluation of the longest running national point-of-use water treatment program that subsidizes and markets dilute sodium hypochlorite under the brand name Clorin in Zambia. During the time of year of the highest sales of Clorin, among households in districts that received considerable social marketing and had the highest per capita sales of Clorin, only 13% of households had residual chlorine in their drinking water at unannounced visits.[13] Rates of use will need to be improved considerably if point-of-use water treatment approaches are to contribute substantially to meeting the millennium development goals.

The Procter & Gamble Company developed a combined flocculant-disinfectant for household water treatment in low-income communities. The flocculant-disinfectant is packaged in sachets designed to treat 10 L of contaminated water. The water treatment process combines precipitation, coagulation, and flocculation with chlorination. It aggregates and facilitates the removal of suspended organic matter, bacteria, viruses, parasites, and heavy metals in treated water.[14] Two health outcome efficacy studies of the flocculant-disinfectant were conducted in Guatemala between 2001 and 2003. The first study found that children living in households that were randomly assigned to receive the flocculant-disinfectant had 25–29% fewer days of diarrhea, although use of the product was suboptimal.[15] The second study tested a modified form of the flocculant-disinfectant with a lower dose of chlorine to improve taste, and used village women to actively encourage use. Households receiving the intervention reported 39% fewer days of diarrhea than control households.[16]

Three weeks after the second health outcome efficacy study was complete, national marketing of the flocculant-disinfectant was extended into the region where the efficacy studies had been conducted. We returned to the study population 6 months later to assess purchase and use of the flocculant-disinfectant and to identify characteristics associated with purchase and use of the flocculant-disinfectant after the product was no longer provided free of cost to participants.

MATERIALS AND METHODS

Setting. This study was conducted in the state of San Juan Sacatepéquez, Guatemala, 30 km northwest of Guatemala City. The participating communities lived in 12 villages spread across adjoining mountains. In this region, the infant mortality rate was 47.7 per 1,000 inhabitants,[17] and 51% of children in their first year of school met the WHO's criteria for moderate or severe stunting.[18] Most households did not have running water. Families walked to collect water from springs, streams, or wells. Available water is typically contaminated with fecal organisms.[19]

Previous efficacy trial. Between November 4, 2002 and January 31, 2003, 514 households participated in a randomized controlled trial of flocculant-disinfectant to treat their drinking water.[16] Two hundred fifty-seven households were randomly assigned to receive the flocculant-disinfectant; 257 households were assigned as controls. Field workers provided intervention households with the supplies needed to use the flocculant-disinfectant and to safely store treated water. Thirteen local women were trained as field educators for the intervention households. They used flocculant-disinfectant in their homes and visited the intervention households one to two times per week during the 13-week efficacy trial. They explained how to treat water, emphasized the importance of providing only treated water for drinking, especially to the youngest children, answered questions, and helped mothers integrate regular water treatment into their understanding and daily practice.

During the course of the 13-week study, households receiving the flocculant-disinfectant experienced 39% fewer days with diarrhea than control households.[16] At the end of the study, field workers gave 21 sachets of the flocculant-disinfectant to each intervention and control household. Field workers taught residents of the control households how to use the product, and told them that using the flocculant-disinfectant to treat water would reduce the frequency of diarrhea.

Flocculant-disinfectant marketing. Within 3 weeks of the end of the trial, an intensive marketing campaign was extended into San Juan Sacatepéquez by the manufacturer of the flocculant-disinfectant. Similar to the national product marketing campaign throughout Guatemala, it included provision of product and advertising materials to small stores throughout the region, local fairs where the product was shown, and advertisements on radio. The retail price of a single sachet of the flocculant-disinfectant sufficient to treat 10 L of water was 1 Guatemala Quetzal (US$0.14). The $0.14 price was projected to be sufficient for complete cost recovery, including cost of production, marketing, and profit along the distribution chain if enough product was consistently sold. The only difference between the product sold in the national marketing campaign and the product used during the efficacy study was that, during the efficacy study, the product was supplied in generic unbranded sachets.

Purchase assessment. In August 2003, 6 months after the efficacy study was completed and while ongoing product marketing continued, field workers returned to each of the households that had participated in the efficacy study, and if the household representative consented, administered a questionnaire on flocculant-disinfectant purchasing practices and use. Field workers asked to see any sachets, either used or unopened, of flocculant-disinfectant in the household. Field workers collected a drinking water sample and tested it for the presence of total chlorine using the *N,N*-diethyl-*p*-phenylenediamine colorimetric method (Hach Company, Loveland, CO).

Field workers also identified each of the retail outlets located in the 12 study villages and interviewed the store proprietors about flocculant-disinfectant sales.

Statistical methods. All of the data were double entered into an electronic database. The household data on post-trial flocculant-disinfectant purchase and use were linked to the efficacy trial data on household characteristics and disease experience.

We hypothesized that households that had received flocculant-disinfectant during the efficacy trial, and therefore were part of the group that had experienced a 39% reduction in diarrhea prevalence, would be more likely to become long-term users of flocculant-disinfectant compared with persons who had been randomized to the control group.

We classified households as active repeat users of flocculant-disinfectant if they reported purchasing the product within the last 2 weeks, using it within the previous week, and had at least one unopened sachet in the household that was observed by the field workers.

Characteristics of households that were active repeat users of the flocculant-disinfectant were compared with households that did not become active repeat users using relative risks and 95% confidence intervals (CIs). CIs that excluded 1.0 were considered unlikely to be caused by chance.

Ethics. All study participants provided informed consent. The Ethics Committee Review Board at the Universidad del Valle de Guatemala and an Institutional Review Board at the Centers for Disease Control (CDC) reviewed and approved the study protocol.

RESULTS

Of 514 households that completed the efficacy study, 462 (90%) completed a follow-up evaluation. Most participating households (82%) had electricity, and many owned durable consumer goods, although house construction was primarily from mud, and levels of maternal literacy were low (25%; Table 1). Thirty-nine percent collected drinking water from a river or stream; 49% defecated on the ground. Compared with households that did not participate in the follow-up, households that participated were somewhat more likely to have a literate mother, drinking water that came from a tap, and own a television; they were somewhat less likely to have been originally assigned to the flocculant-disinfectant group (Table 1).

All but one household (99.8%) reported using the flocculant-disinfectant at least once, and 388 (84%) reported that use of the flocculant-disinfectant improved the taste of their drinking water. However, only 66 (14%) reported using the flocculant-disinfectant in the preceding week, only 34 (7%) had bought the flocculant-disinfectant more than six times, only 22 households (5%) met the criteria for active repeat use, and only 7 households (1.5%) had detectable chlorine in their drinking water (Table 2). Among the 22 households that met the criteria for active repeat use, only 4 (18%) had detectable chlorine in their drinking water at the time of the

TABLE 1
Comparison of participating households to those lost to follow-up

Household characteristic	Follow-up households [% (*N*)] (*N* = 459)*	Households not reached for follow-up [% (*N*)] (*N* = 52)
Maternal literacy	25 (117)	9 (17)
Paternal literacy	66 (305)	58 (30)
House constructed primarily with mud	66 (301)	81 (42)
Number of persons living in the household†	2.4 (6.3)	2.2 (5.8)
Had electricity	82 (378)	75 (39)
Own		
Land for farming	27 (122)	27 (14)
Television	44 (203)	33 (17)
Bicycle	41 (190)	48 (25)
Radio	73 (335)	71 (37)
Drinking water sources‡		
Tap	35 (162)	19 (10)
River or stream	39 (179)	44 (23)
Well	31 (140)	46 (24)
Site of defecation		
Latrine	47 (215)	40 (21)
Toilet	2 (11)	2 (1)
Outside on the ground	49 (226)	58 (30)
Originally assigned to receive flocculant-disinfectant	49 (223)	62 (32)

* Baseline household characteristic data were unavailable for three households.
† Mean (SD).
‡ Some households had multiple water sources.

visit. Six of the seven households with detectable chlorine reported using the flocculant-disinfectant within the last week.

Nearly all households (*N* = 430, 93%) reported that they would regularly treat their water with the flocculant-disinfectant if the price per sachet were reduced to one half of its marketed price (i.e., from US$0.14 to US$0.07). When asked to choose one aspect of the flocculant-disinfectant that they did not like from a list, 187 (41%) chose price, 170 (37%) complained that they were unable to find it in the store, 63 (14%) said it took too much time to prepare, and 38 (8%) reported that it made their drinking water taste bad.

In 1 of the 12 study villages, none of the 16 respondents reported knowing where they could purchase the flocculant-disinfectant nearby. Among the 446 respondents who lived in villages where the flocculant-disinfectant was available for purchase, 22 households (5%) met the criteria of active repeat users. Active repeat users reported using a mean of four sachets in the preceding week (range, 1–7 sachets).

We compared the characteristics of the 22 households that were active repeat users of the flocculant-disinfectant to 424 households from communities where the flocculant-disinfectant was sold but that were not active repeat users (Table 3). The only characteristics that were associated with becoming an active repeat user of the flocculant-disinfectant was a stated belief that the household drinking water was dirty and a belief that the household drinking water made the family ill. Whether a household was randomized to receive the flocculant-disinfectant in the efficacy trial was not significantly associated with becoming an active repeat user (Table 3).

In the week preceding the survey, participating households reported spending a median of US$1.3 (interquartile range [IQR], 0.65, 1.56) on laundry soap, US$0.65 (IQR, 0, 0.91) on toothpaste, and US$0 [IQR, 0, 0.49] on hand soap. Households that were active repeat users of the flocculant-disinfectant reported similar combined expenditures on these consumer items compared with households that were not active repeat users (mean, US$2.07 versus US$2.06; $P = 0.97$).

Diarrhea was common. Eighty-eight percent of control households and 69% of intervention households reported at least one episode of diarrhea during the 13-week efficacy trial. Households that ultimately became active repeat users of the flocculant-disinfectant had a similar proportion of child days of diarrhea during the study period in their household compared with households that did not become active repeat users (2.9% versus 2.7%, $P = 0.73$). Among households that were assigned to the flocculant-disinfectant during the study period, the 13 households that became active repeat users had a somewhat higher proportion of child days of diarrhea during the study period, compared with non-users, but with such a small number of observations, the difference was no larger than would be expected by chance (2.8% versus 2.0%, $P = 0.29$).

The field workers identified 96 retail shops serving the study communities. Seventy-two (75%) were familiar with the flocculant-disinfectant; 48 (50%) had sold it in their shop at least once, 38 (40%) had advertising for the flocculant-disinfectant visible, and 28 (29%) reported selling the flocculant-disinfectant within the preceding week. They sold a median of 3 sachets (range, 1–36 sachets) in the preceding week. Twenty-four (25%) had flocculant-disinfectant sachets in stock; 69 proprietors (72%) expressed interest in selling the flocculant-disinfectant in the future.

TABLE 2
Flocculant-disinfectant use

Characteristic	Among households originally assigned to flocculant-disinfectant [% (*N*)] (*N* = 226)	Among households originally assigned to control [% (*N*)] (*N* = 236)	Total [% (*N*)] (*N* = 462)
Use			
Had used the flocculant-disinfectant at least once	99.6 (225)	100 (236)	99.8 (461)
Had used the flocculant-disinfectant within the last week	13 (29)	16 (37)	14 (66)
Had one or more flocculant-disinfectant sachets in the household	12 (26)	19 (46)	16 (72)
Had detectable chlorine in drinking water	2.7 (6)	0.4 (1)	1.5 (7)
Purchase			
Knew a store nearby that sold the flocculant-disinfectant	54 (123)	54 (126)	54 (249)
Had ever bought a sachet of the flocculant-disinfectant	24 (55)	25 (58)	24 (113)
Had bought the flocculant-disinfectant within the last 2 weeks	11 (27)	13 (29)	12 (56)
Had bought the flocculant-disinfectant more than six times	9 (21)	6 (13)	7 (34)
Met criteria for active repeat use*	6 (13)	4 (9)	5 (22)

* Reported purchasing the product within the last 2 weeks, using it within the previous week, and had an unopened sachet in the household that was observed by the field workers.

TABLE 3
Relationship between household characteristics and active repeat use of the flocculant-disinfectant

Characteristic	Proportion with this characteristic who were active repeat users [% (*N*)]	Proportion without this characteristic who were active repeat users [% (*N*)]	Relative risk (95% CI)
Randomized to receive flocculant-disinfectant in the efficacy trial	5.9 (13)	4.0 (9)	1.5 (0.65, 3.4)
Maternal literacy	6.1 (7)	4.3 (14)	1.4 (0.59, 3.4)
Paternal literacy	5.0 (15)	4.1 (6)	1.2 (0.49, 3.1)
House constructed primarily with mud	6.9 (11)	3.9 (11)	1.8 (0.79, 4.0)
Had electricity	4.7 (17)	5.1 (4)	0.92 (0.32, 2.7)
Own			
Land for farming	7.0 (8)	4.0 (13)	1.8 (0.75, 4.1)
Television	6.1 (12)	3.7 (9)	1.6 (0.71, 3.8)
Bicycle	4.3 (8)	5.1 (13)	0.84 (0.36, 2.0)
Radio	4.3 (14)	5.8 (7)	0.74 (0.31, 1.80)
Drinking water sources*			
Tap	5.6 (9)	4.6 (13)	1.2 (0.53, 2.8)
River or spring	4.3 (7)	5.3 (15)	0.80 (0.33, 1.9)
Well	2.9 (4)	4.0 (18)	0.49 (0.17, 1.4)
Believe that diarrhea is a problem	5.5 (22)	0 (0)	Undefined ($P = 0.15$)
Knew someone who died of diarrhea in the last few years	6.9 (16)	2.8 (6)	2.4 (0.98, 6.2)
Believe that actions they take can prevent illness in their child	5.5 (21)	1.6 (1)	3.4 (0.47, 25)
Believe that their water source is good	4.5 (15)	6.4 (7)	0.70 (0.29, 1.7)
Believe that their drinking water is dirty	8.7 (16)	2.3 (6)	3.8 (1.5, 9.4)
Believe that drinking water makes their family sick	7.0 (20)	1.2 (2)	5.6 (1.3, 24)

* Some households had multiple water sources.

DISCUSSION

In San Juan Sacatepéquez, where diarrhea is a leading cause of childhood death and drinking water is highly contaminated, only 5% of households had recently purchased and used the flocculant-disinfectant, and only 1.5% had detectable chlorine in their drinking water. This low rate of use is remarkable because an efficacy study in the same population showed a 39% reduction in diarrhea with use of the product; each of the households received sample product and a personal demonstration on how to use it; the product was available in many local stores; and was actively marketed by one of the most successful global manufacturers of home consumer products. This 5% rate of active repeat users is the same as the rate achieved throughout the country.[20]

We do not know why such a small proportion of the target population became active repeat users of the flocculant-disinfectant. One reason may be the price of the product. This was the most frequently mentioned (41%) negative characteristic of the product. Indeed, the flocculant-disinfectant is more costly than most other point-of-use water treatment approaches.[21] During the efficacy trial, households averaged using 10 sachets per week,[16] which would cost US$1.40 per week to purchase, the equivalent of 60% of the average household weekly spending for laundry soap, toothpaste, and hand soap. Ninety-three percent of respondents said they would use the product if it were one half of its marketed price; however, an expressed willingness to pay is a poor predictor of actual purchasing behavior.[22] Households that became active repeat users were not notably wealthier than those households that were not active repeat users. They had similar household assets and spent a similar amount on other household consumer items. Indeed, Procter & Gamble's internal marketing assessment was that price was not the reason for low uptake.[20] It is also possible that households were reluctant to purchase a product that they had earlier received free of cost; however, because the rates of purchase in these study villages were similar to the rate of purchase nationally, the prior provision of free supplies does not explain the low level of purchase.

A second barrier to more widespread use may have been the time required to use the product. Female heads of household already spent substantial time collecting water and on other innumerable household tasks required for family survival in a low-income setting. Using the flocculant-disinfectant required extra steps for water treatment and extra time spent washing the filter cloths.

Although the taste is a potential barrier to use of chlorine-containing water treatments, the flocculant-disinfectant reduces the concentration of organic compounds in water, which would be expected to improve taste. Indeed, 84% of household respondents reported that the flocculant-disinfectant did improve the taste of their drinking water, so bad taste does not seem to have been a major barrier to more widespread use.

It is possible that the flocculant-disinfectant was sufficiently attractive to the population to become a sustainable consumer product, but the marketing strategy was ineffective. Indeed, Procter & Gamble continues to sell the flocculant-disinfectant in other settings for emergency relief[23] and through subsidized non-governmental organizational approaches.[24] However, the approaches used to market flocculant-disinfectant in Guatemala were the same approaches that have been used to successfully market a wide range of consumer products globally.

We did not measure more general satisfaction with the flocculant-disinfectant in either the second efficacy study nor in this follow-up evaluation, but in the first efficacy study, flocculant-disinfectant users also expressed widespread satisfaction, including 89% of users rating their treated water as good or very good,[15] and 89% reporting that the time and effort to prepare the water was worth it (unpublished observations). Taken together, these data suggest that neither reported satisfaction nor efficacy in reducing diarrhea is sufficient to predict public health benefit of a point-of-use water treatment intervention.

Although the data analysis of the efficacy study showed a 39% lower prevalence of diarrhea among households that used flocculant-disinfectant, households randomized to receive the flocculant-disinfectant during the efficacy study were not significantly more likely to become active repeat users than households randomized to the control group. Diarrhea episodes are highly variable. Most intervention households (69%) still experienced diarrhea during the efficacy study. Households that were treating their water may not have recognized a lower rate of diarrhea or attributed any reduction to water treatment. Thus, achieving the population health benefit of the intervention (i.e., reduced diarrhea) was itself not sufficient motivation for families to purchase and use the product. This suggests that motivating people to treat their water at home will need to depend on something other than recognizing a reduction in diarrhea. The single factor that was most strongly associated with becoming an active repeat user was a belief that drinking water made their family sick; however, only 7% of respondents who expressed this attitude became active repeat users.

Even the few active repeat users would not be expected to experience the same health benefit as participants did during the efficacy study. The efficacy of the water treatment in preventing diarrhea seems to be associated with the amount of product used.[11,25] During the first study of flocculant-disinfectant efficacy in Guatemala, households assigned to flocculant-disinfectant used an average of six sachets per week and had a 25–29% reduction in diarrhea compared with control households.[15] During the second Guatemala study, intervention households used an average of 10 sachets per week and had a 39% reduction in diarrhea.[16] In contrast, the active repeat users who purchased the flocculant-disinfectant 6 months after the study ended reported purchasing a mean of four sachets in the preceding week, and only 18% of the active repeat users had detectable chlorine in their drinking water at the time of the assessment. If other point-of-use water treatment approaches are also found to be used only intermittently, the health outcome of such intermittent use should be evaluated.

There are important limitations to the conclusions that can be drawn from this study. First, this was a study of a single type of point-of-use water treatment product in a small part of a single country after 6 months of active intervention. It is possible that other settings, other approaches to household water treatment or longer time frames would yield different outcomes. In this case, the proportion of long-term repeat purchasers in the national market in Guatemala was similar to the study area. Indeed, the proportion of repeat customers was too low in Guatemala for the Procter & Gamble Company to develop a sustainable market model, and so they discontinued marketing the flocculant-disinfectant in Guatemala. When similar low rates of long-term use were noted in national level test markets in three other counties, the Procter & Gamble Company withdrew the product from normal commercial distribution.[20] Other household water treatment technologies or other distribution approaches may prove successful in reaching a large proportion of at risk populations with a sustainable distribution strategy and a level of use that prevents diarrhea; however, the failure of a well-funded effort by a highly skilled marketing company using an effective intervention suggests that success will prove difficult to achieve. Indeed, in a recent review of seven different point-of-use water treatment approaches, all required ongoing subsidies to promote use,[26] a factor that limits their impact when each day well over one billion people are currently drinking water that needs additional treatment.

A second limitation of the study is that we may have misclassified some persons as active repeat users. Participants may have over-reported use to try and meet the expectations of interviewers. Indeed only 18% of households that were active repeat users had detectable chlorine in their drinking water. Sachets in the household may have been leftover from the 21-day supply that was given at the end of the efficacy study. On the other hand, households may have been fairly consistent users, but happened not to have sachets at home the moment when interviewers visited. Even if use was over-reported, it was still low by report and even lower by chemical confirmation. The levels of use reported in household interviews were generally consistent with national use levels and with sales reported from local stores, so the measured proportion of active repeat users seems credible.

A third limitation is that the study identified only 22 active repeat users, so there was limited power to evaluate factors associated with use. Moreover, because the control group also received 21 sachets at the end of the study, they may also have noted a positive health benefit and so undercut the comparison. Although the study had a limited capability to measure precisely the association of various household factors to active repeat use, no household characteristic was associated with > 9% of households being active regular users. Thus, the available data are sufficient to conclude that no household factor was associated with a high frequency of active repeat use.

A fourth limitation is that data from 10% of households from the original study were not available. These households were somewhat different at baseline and so their inclusion could have changed some results. However, given the consistent low levels of use found among studied households of all characteristics, it is unlikely that data from these additional households would affect the principle conclusions of this analysis.

Well over one billion people regularly drink fecally contaminated water. The flocculant-disinfectant is largely efficacious in treating this water. It cleans water and reduces diarrhea. However, there are multiple barriers in moving from technical efficacy to public health effectiveness in reaching impoverished populations. Some strategies to improve uptake of point-of-use water treatment including increased community mobilization, clinic-based promotion, and use of local micro-entrepreneurs have been successful in limited settings[27,28] (A Dubois, personal communication). Future research efforts to assess and improve the effectiveness and sustainability of large-scale point of use water treatment interventions are essential if these interventions are ever to contribute substantially to the well over one billion people whose drinking water is contaminated. Unless point-of-use water treatment interventions can achieve substantially higher rates of use across broad populations than the flocculant-disinfectant did in these Guatemalan villages, the public health benefit will be modest.

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