Impact of the Integration of Water Treatment and Handwashing Incentives with Antenatal Services on Hygiene Practices of Pregnant Women in Malawi

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Abstract. Access to safe drinking water and improved hygiene are important for reducing morbidity and mortality from diarrhea. We surveyed 330 pregnant women who participated in an antenatal clinic-based intervention in Malawi that promoted water treatment and hygiene through distribution of water storage containers, sodium hypochlorite water treatment solution, soap, and educational messages. Program participants were more likely to know correct water treatment procedures (62% versus 27%, $P < 0.0001$), chlorinate drinking water (61% versus 1%, $P < 0.0001$), demonstrate correct handwashing practices (68% versus 22%, $P < 0.0001$), and purchase water treatment solution after free distribution (32% versus 1%, $P < 0.0001$). Among participants, 72% had at least three antenatal visits, 76% delivered in a health facility, and 54% had a postnatal check. This antenatal-clinic-based program is an effective new strategy for promoting water treatment and hygiene behaviors among pregnant women. Participants had high use of antenatal, delivery, and postnatal services, which could improve maternal and child health.

INTRODUCTION

Diarrheal illness is a leading cause of mortality in children < 5 years of age in the developing world.¹ In Malawi, where < 5 years of age mortality is high, at 122 per 1,000 live births, a national survey found that nearly 24% of children < 5 years of age had a diarrhea episode in the preceding 2 weeks.² Several key practices reduce the risk of diarrheal diseases: use of household water treatment, handwashing with soap, use of improved sanitation, and exclusive breastfeeding of infants.^{3–8} To reduce diarrhea risk in Malawi, a household water treatment product (brand name WaterGuard) was launched in 2002 by Population Services International (PSI, Blantyre, Malawi). A 2005 survey showed that while 65% of mothers had heard of WaterGuard, reported current use was 7%.⁹

In 68 countries that have 97% of maternal and child deaths, 88% of women reported at least one antenatal visit, suggesting that antenatal care could be a productive platform for integrating interventions to improve maternal and child health.¹⁰ In Malawi, although 92% of pregnant women receive some antenatal care from a skilled provider, deliveries in health facilities (54%) and postnatal checks (33%) are less common, contributing to high maternal mortality at 807 deaths per 100,000 live births.²

To assess whether a strategy to integrate water treatment and handwashing promotion through antenatal care programs would improve home hygiene and increase use of perinatal services in Malawi, we implemented a pilot program in 15 health facilities in two districts in May 2007. In this program, 15,000 pregnant women received free hygiene kits (Figure 1) consisting of a water storage container with a tap, a bottle of WaterGuard, a bar of soap, and two sachets of oral rehydration salts during the first antenatal clinic visit after program implementation. Women were eligible to receive up to three free refills of WaterGuard and soap during subsequent antenatal visits, at delivery, or during postnatal checkups. In March 2008, we evaluated the program impact on water treatment

and hand hygiene practices of women receiving care in target health facilities.

METHODS

Evaluation design, sampling, and enrollment. We conducted a baseline cross-sectional survey of pregnant women receiving care at 15 antenatal clinics in Blantyre and Salima districts where the program was implemented. Pregnant women received hygiene kits after completion of the baseline. We performed a follow-up survey of the same women after 9 months. To determine whether hygiene behaviors diffused to other persons, we asked pregnant women to identify non-pregnant relatives or friends with children < 5 years of age and included one for each pregnant woman in the evaluation; these results are presented elsewhere.

Using a formula for comparing two correlated proportions, we calculated a minimum sample size of 338, assuming 7% overall use of WaterGuard at baseline based on a previous national survey, 100% increase in use in response to the intervention based on prior experience with water treatment interventions, and a proportion discordant equal to 20%, based on a type I error of 5% and a power of 80% (PASS 2008 v 8.06).^{9,11,12} A target sample size of 400 was set to account for loss to follow-up.

We enrolled 400 pregnant women in April–May 2007 by selecting a weighted sample of pregnant women from each health facility proportional to the average monthly antenatal clinic attendance. We approached every third woman waiting to receive antenatal services for survey enrollment to complete enrollment from each health facility in 1 week. We used standardized questionnaires at baseline to collect data on demographic and socioeconomic characteristics; water sources; and water storage, treatment, and hygiene practices. Participants were interviewed by trained staff in the health facilities before program implementation occurred. We then made observations in the participants' homes regarding water storage and treatment practices, presence of soap, and demonstration of handwashing procedure. We tested stored drinking water for residual chlorine using the N,N-diethyl-p-phenylenediamine (DPD) colorimetric method using Hach

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FIGURE 1. Hygiene kits consisting of a covered water storage container with a tap, a bottle of WaterGuard, a bar of soap, two sachets of oral rehydration salts, and an instructional brochure.

Free and Total Chlorine kits (Hach Co., Loveland, CO) as an objective measure of WaterGuard use. In February–March 2008, trained enumerators conducted follow-up interviews and home observations of all participants during surprise visits to assess whether their practices had changed as a result of the program using a questionnaire that was identical to the baseline questionnaire except for additional questions on the hygiene kit program.

Program implementation. After completion of the baseline survey and home observations, participants received hygiene kits and instructions for their use. Participants were told that they would receive refills of WaterGuard and soap on up to three return antenatal visits. In preparation for program implementation, PSI conducted a training of health facility staff members on patient communication, hand hygiene techniques, and appropriate water storage, handling, and treatment with WaterGuard. Antenatal clinic staff members were instructed to incorporate these water treatments and hand hygiene educational messages into antenatal clinic activities. Health Surveillance Assistants (Ministry of Health employees who provide community health services, hereafter referred to as HSAs) were encouraged to reinforce hygiene kit use by demonstrating correct use of WaterGuard and handwashing during periodic home visits; each HSA was encouraged to visit at least five women in the program per month. Finally, PSI ensured that social marketing and WaterGuard reached target communities through increased radio advertisements, billboards, and distribution of WaterGuard to commercial sales outlets in the program area.

Cost analysis. We solicited cost information from each of the key stakeholders responsible for program implementation: Ministry of Health, United Nations Children's Fund (Malawi), and PSI (Malawi). Costs included health facility personnel training and time, commodities (hygiene kits components and refills), product distribution, and increased social marketing in the targeted health facilities' catchment areas during the program period. Health facility personnel time was estimated on the basis of a survey of health facility staff involved in program implementation.

Human subjects protection. The Centers for Disease Control and Prevention (CDC) Human Subjects Contact

determined that, because this activity consisted of an evaluation of a proven public health practice, it was exempt from human subjects research oversight. Oral informed consent was obtained from all survey participants and personal identifiers were permanently removed from the database.

Data analysis. Data from baseline and follow-up surveys were entered into a Microsoft (Redmond, WA) Access 2003 database and analyzed using SAS software version 9.2 (Cary, NC) and SUDAAN version 10.0.1 (Research Triangle Park, NC). To classify respondents by socioeconomic status, we used principal component analysis methodology in which household assets were assigned values based on a scoring factor as described by Filmer and Pritchett.¹³ Asset indicators included ownership of consumer durables, observed characteristics of the household dwelling, and land ownership. Asset values were summed for each participant to create a household asset score.¹³ Respondents were placed in socioeconomic quintiles based on their asset score relative to their district's survey population.

Comparisons between the two districts on baseline demographics and perinatal outcomes were done using the Wald F-test accounting for clustering by health facility by the Taylor series method of variance estimation (SUDAAN). The primary outcomes of interest included confirmed WaterGuard use (defined as presence of a WaterGuard bottle in the home and detectable residual chlorine in stored water) and lathering hands completely with soap during a handwashing demonstration. Baseline and follow-up data were summarized and compared using McNemar's test for paired proportions adjusting for clustering by health facility.¹⁴ For a few instances where the adjustment to McNemar's test was not feasible, an exact test of a binomial proportion was used when necessary. To assess factors associated with confirmed use of WaterGuard, purchase of WaterGuard, and correct handwashing demonstration at follow-up among the subset of participants who did not exhibit these behaviors at baseline, bivariate odds ratios (OR) were estimated by a logistic regression model adjusting for district. The Taylor series method of variance estimation was used to account for stratification by district and clustering by health facility (SUDAAN).

RESULTS

Evaluation enrollment. At baseline, we enrolled 231 pregnant women attending eight health facilities in Blantyre District and 158 women from seven health facilities in Salima District. Six women were excluded from each district because of poor data quality. During the follow-up survey, 49 (21%) women in Blantyre District and 10 (6%) in Salima District were lost to follow-up; the reasons included moved away (89%), refused to participate (3%), died (2%), and other (6%). Data from the remaining 182 women from Blantyre and 148 from Salima were included in the analyses. Compared with those who completed the follow-up survey, a higher proportion of respondents lost to follow-up lived in urban areas (63% versus 30%), lived in Blantyre District (83% versus 55%), completed primary school (49% versus 29%), and were able to read (83% versus 61%). For this analysis, women lost to follow-up were omitted.

Baseline demographic and socioeconomic characteristics. Baseline demographic and socioeconomic characteristics of respondents are presented for each district in Table 1.

TABLE 1

Baseline demographics, socioeconomic characteristics, water source, water storage, and sanitation facilities of participants in the integrated hygiene promotion-antenatal clinic program, Blantyre and Salima Districts, Malawi, May–June 2007

Characteristic (%)	Blantyre (N* = 182)	Salima (N* = 148)	Total (N* = 330)
Median age at enrollment (range)†	23 (15–41)	25 (16–45)	24 (15–45)
Median household size at enrollment (range)†	4 (1–10)	4 (2–9)	4 (1–10)
Median no. children < 5 yrs at enrollment (range)†	1 (0–4)	1 (0–3)	1 (0–4)
Rural residence‡	92 (51)	140 (95)	232 (70)
Education‡			
None	16 (9)	55 (37)	71 (22)
Some primary school	90 (50)	73 (49)	163 (50)
Completed primary school	23 (13)	11 (7)	34 (10)
More than primary school	51 (28)	9 (6)	60 (18)
Literate‡	137 (77)	62 (42)	199 (61)
Improved primary water source	168 (93)	124 (84)	292 (89)
Household or yard tap	65 (36)	8 (5)	73 (22)
Public tap	26 (14)	3 (2)	29 (9)
Protected borehole, well, or stream	77 (43)	113 (77)	190 (58)
Latrine observed inside or near home‡	164 (90)	110 (75)	274 (83)
Stores drinking water	182 (100)	146 (99)	328 (99)
Primary water storage container‡			
Bucket	126 (70)	34 (23)	160 (49)
Clay pot	42 (23)	110 (76)	152 (47)
Other (Jerry can, bottle, tank, basin)	12 (7)	1 (1)	13 (4)

* For some items, N may vary by small numbers.

† Medians were not compared by a statistical test.

‡ $P < 0.05$ by Wald F-test accounting for clustering by health facility.

Respondents had a median of one child < 5 years of age (range 0–4 children) at the time of enrollment. A lower proportion of Blantyre respondents reported rural residence compared with Salima (51% versus 95%), and a higher proportion of Blantyre respondents reported completing primary school (41% versus 13%) and being able to read (77% versus 42%).

Program implementation. Of 330 respondents at follow-up, 138 (45%) had received three refills of WaterGuard and soap, 99 (33%) obtained two refills, 48 (16%) received one, and 19 (6%) received none. The HSAs made at least one home visit to 91% of participants (84% in Blantyre and > 99% in Salima), and three or more visits to 53% of participants (26% in Blantyre and 87% in Salima). The median number of HSA visits was one in Blantyre District (range 0–8) and five in Salima District (range 0–10). Nearly all (99%) participants reported that the HSA showed WaterGuard use and handwashing during the visit.

Pregnancy indicators. Participants were all in their third to ninth month of pregnancy at enrollment (Table 2). At follow-up, 90% of respondents from Blantyre and 59% from Salima reported delivering in a health facility, and 68% of respondents from Blantyre and 37% from Salima had a postnatal check. At follow-up, 94% said that their babies were still alive; 91% of babies had been seen at least once by a health care provider.

Water source, storage, and treatment. At baseline, 93% of Blantyre residents and 84% of Salima residents reported using an improved drinking water source; 99% of total respondents reported storing their drinking water, and 93% used a storage container that was covered (Tables 1 and 3). At follow-up, 91% were observed to be using the hygiene kit bucket, and 97%

TABLE 2

Antenatal clinic attendance, delivery site, and pregnancy outcomes of participants in the integrated hygiene promotion-antenatal clinic program, Blantyre and Salima Districts, Malawi, February–March 2008

Characteristic (%)	Blantyre (N* = 182)	Salima (N* = 148)	Total (N* = 330)
Median months gestation at enrollment (range)†	7 (3–9)	6 (3–9)	7 (3–9)
First pregnancy‡	48 (26)	24 (16)	72 (22)
Visits to health facility during pregnancy			
1 visit	10 (7)	6 (5)	16 (6)
2 visits	31 (20)	27 (23)	58 (21)
3 visits	55 (36)	46 (39)	101 (37)
4 visits	45 (30)	29 (24)	74 (27)
4 visits	11 (7)	11 (9)	22 (8)
Where delivered‡			
Home or neighbor's home	16 (9)	55 (37)	71 (22)
Clinic/hospital/health center	162 (90)	88 (59)	250 (76)
On the way to the clinic	3 (2)	5 (3)	8 (2)
Postnatal check after delivery‡	113 (68)	50 (37)	163 (54)
Infant alive at birth	150 (94)	119 (96)	269 (95)
Baby still alive	170 (93)	140 (95)	310 (94)
Baby seen by health care provider	151 (89)	131 (94)	282 (91)

* For some items, N may vary by small numbers.

† Medians were not compared by a statistical test.

‡ $P < 0.05$ by Wald F-test accounting for clustering by health facility.

used a storage container that was covered [$P = 0.02$ (Table 3)]. At baseline, only 2% removed drinking water from their water storage container by pouring or using a tap compared with 52% at follow-up ($P < 0.0001$). At baseline, 73% of respondents reported that they treated their drinking water compared with 99% at follow-up ($P < 0.0001$). The most common treatment methods reported at baseline were WaterGuard (41%), boiling (35%), and chlorine stock solution distributed by the Ministry of Health (13%). At follow-up, reported treatment methods included WaterGuard (91%), boiling (16%), and stock chlorine (12%). At baseline, 36% reported treating their water by any method in the past 2 days compared with 82% at follow-up ($P < 0.0001$).

WaterGuard knowledge and use. At baseline, 97% of respondents in Blantyre and 71% in Salima had heard of WaterGuard, compared with 100% of respondents from Blantyre ($P = 0.03$) and 99% from Salima ($P < 0.0001$) at follow-up (Table 3). Among women in both districts who had heard of WaterGuard, 27% were able at baseline to correctly identify both the dose and wait time compared with 62% at follow-up ($P < 0.0001$). Nearly all participants (97%) reported that someone had taught them how to use WaterGuard; health care providers in the clinic (57%) and community health workers visiting the home (37%) were most commonly mentioned.

At baseline, 19% of respondents reported using WaterGuard in the past 2 days compared with 70% at follow-up (Table 3). WaterGuard bottles were observed in 7% of homes at baseline and 65% of homes at follow-up ($P < 0.0001$). Stored water samples from 9% of homes at baseline had positive chlorine residuals compared with 71% at follow-up ($P < 0.0001$). At baseline, we observed confirmed WaterGuard use in 1% of respondents' homes; at follow-up 61% of homes exhibited confirmed WaterGuard use ($P < 0.0001$).

Of 330 respondents at follow-up, 182 (55%) reported purchasing WaterGuard after receiving one or more free bottles; 100 (32%) reported WaterGuard purchase and exhibited confirmed WaterGuard use [$P < 0.0001$ (Table 3)]. A significantly greater percentage of participants exhibited WaterGuard

TABLE 3

Comparison of knowledge and practices regarding water handling, water treatment, and hand hygiene from baseline to follow-up among participants in the integrated hygiene promotion-antenatal clinic program, Blantyre and Salima Districts, Malawi, 2007–2008

Characteristic (%)	Blantyre (N* = 182)			Salima (N* = 148)			Total (N* = 330)		
	Baseline	Follow-up	P value†	Baseline	Follow-up	P value†	Baseline	Follow-up	P value†
Water storage and handling									
Water storage container has a cover	173 (95)	175 (96)	0.60	132 (91)	146 (99)	< 0.0001	305 (93)	321 (97)	–‡
Hygiene kit bucket used for water storage	NA	158 (87)	NA	NA	141 (95)	NA	NA	299 (91)	NA
Pours or uses tap to remove drinking water	8 (4)	80 (44)	< 0.0001	0	90 (61)	–¶	8 (2)	170 (52)	< 0.0001
Water treatment									
Treats drinking water with any method	143 (79)	164 (99)	< 0.0001	97 (66)	144 (100)	–¶	240 (73)	308 (99)	< 0.0001
WaterGuard	90 (49)	158 (88)	< 0.0001	44 (30)	141 (95)	< 0.0001	134 (41)	299 (91)	< 0.0001
Boiling	71 (39)	32 (18)	0.0007	45 (30)	22 (15)	0.02	116 (35)	54 (16)	0.0002
Treat with chlorine stock solution	17 (9)	25 (14)	0.19	27 (18)	13 (9)	0.006	44 (13)	38 (12)	0.48
Other (filter, settle, flocculant)	31 (19)	2 (1)	< 0.0001	27 (22)	15 (10)	0.07	58 (21)	17 (5)	< 0.0001
Reported use of any method in past 2 days	64 (36)	120 (74)	< 0.0001	51 (35)	132 (92)	< 0.0001	115 (36)	252 (82)	< 0.0001
WaterGuard knowledge and use									
Heard of WaterGuard	176 (97)	182 (100)	–‡	105 (71)	147 (99)	< 0.0001	281 (85)	329 (> 99)	–¶
Knows correct WaterGuard treatment procedure	53 (31)	109 (60)	< 0.0001	23 (22)	95 (65)	< 0.0001	76 (27)	204 (62)	< 0.0001
Ever used WaterGuard	122 (68)	182 (100)	–¶	62 (43)	148 (100)	–¶	184 (57)	330 (100)	–¶
Reported use of WaterGuard in last 2 days	39 (22)	102 (57)	< 0.0001	23 (16)	125 (85)	< 0.0001	62 (19)	227 (70)	< 0.0001
WaterGuard bottle observed in home	11 (6)	93 (51)	< 0.0001	11 (8)	122 (82)	< 0.0001	22 (7)	215 (65)	< 0.0001
Detectable residual chlorine in stored water	20 (11)	98 (57)	0.0004	7 (5)	125 (86)	< 0.0001	27 (9)	223 (71)	< 0.0001
Confirmed WaterGuard use	2 (1)	76 (44)	0.0005	2 (2)	118 (81)	< 0.0001	4 (1)	194 (61)	< 0.0001
Purchased WaterGuard and confirmed use	2 (1)	45 (27)	< 0.0001	2 (2)	55 (39)	0.0006	4 (1)	100 (32)	< 0.0001
Hygiene practices									
Soap observed in home	140 (77)	154 (85)	0.25	96 (66)	116 (78)	0.05	236 (72)	270 (82)	0.05
Handwashing demonstration									
Uses soap	48 (26)	132 (73)	< 0.0001	38 (27)	110 (74)	< 0.0001	86 (27)	242 (73)	< 0.0001
Lathers hands completely with soap	39 (21)	117 (64)	< 0.0001	32 (23)	107 (72)	< 0.0001	71 (22)	224 (68)	< 0.0001
Latrine	164 (90)	174 (96)	0.03	110 (75)	131 (89)	0.009	274 (83)	305 (93)	0.0002

* For some items, N may vary by small numbers.

† P value is from McNemar's test adjusted for clustering by health facility.

NA = not applicable.

‡ P value could not be estimated using McNemar's test adjusting for clustering by health facility, but using an exact test of binomial proportion, $P < 0.05$.

¶ P value could not be estimated using McNemar's test adjusting for clustering by health facility, but using an exact test of binomial proportion, $P < 0.0001$.

purchase and confirmed use at follow-up than at baseline ($P < 0.0001$).

WaterGuard use was confirmed in a higher percentage of households of women attending all 15 health facilities at follow-up, with a statistically significant increase in 14 (93%) facilities. The percentage of households exhibiting purchase and use of WaterGuard also increased in the 15 health facilities, with a statistically significant increase in 11 (73%) facilities.

Hand hygiene. Soap was observed in 72% of homes at baseline and 82% at follow-up [$P = 0.05$ (Table 3)]. When program participants were asked to demonstrate how they washed their hands at baseline, 27% used soap and 22% lathered their hands completely with soap. At follow-up, 73% used soap ($P < 0.0001$) and 68% lathered their hands completely with soap ($P < 0.0001$). The percentage of participants who lathered their hands completely with soap increased in all 15 health facilities at follow-up, with a statistically significant increase in 14 (93%) facilities (Table S1).

Factors associated with improved water treatment and hand hygiene practices. Among participants who lacked confirmation of WaterGuard use at baseline, there was a significant association, controlling for district, at follow-up between confirmed WaterGuard use and rural residence, being in the lower three wealth quintiles, not completing primary school, having primary source water not from a tap, receiving all three hygiene kit refills, and receiving three or

more home visits by HSAs (Table 4). Having over five HSA home visits was associated with WaterGuard purchase and confirmed use at follow-up. Among participants who did not demonstrate correct handwashing procedures at baseline, correct handwashing at follow-up was associated with being able to read and receiving at least four HSA home visits.

Cost analysis. The unit cost of a hygiene kit and three refills was US\$ 4.71. To calculate program implementation costs to the health facilities, 240 health facility staff members were surveyed. They reported a median of 10, 15, and 20 minutes spent on record keeping, patient education, and hygiene kit assembly, respectively, per antenatal clinic day. The HSAs reported a median of 15 minutes for each home visit. The total program cost (including the kit and refills) per hygiene kit recipient was US\$ 9.01. Of this program cost, 70% was spent on commodities and their distribution, educational materials, and advertising; 17% on salaries paid to health facility and PSI staff for program implementation; and 13% on coordination expenses.

Assuming a median of five household members at follow-up, a program cost of US\$ 9.01 per program participant, and a frequency of WaterGuard purchase and confirmed use after program completion of 32%, the estimated cost per household member benefiting from household use of WaterGuard associated with this program is US\$ 5.63, not including any cost savings that may have occurred from a reduced risk

TABLE 4

Bivariate analysis of demographic, socioeconomic, and program characteristics and adoption of key water treatment and hand hygiene behaviors among participants without these behaviors at baseline, Blantyre and Salima Districts, Malawi, 2007–2008

	Confirmed WaterGuard use (aOR, 95% CI)* N† = 364	Purchased WaterGuard and confirmed use (aOR, 95% CI)* N† = 364	Correct handwashing demonstration (aOR, 95% CI)* N† = 296
Demographics, socioeconomics, and source water			
Salima District	5.60 (1.50–20.93)	1.73 (0.51–5.89)	1.72 (0.89–3.35)
Rural residence	4.00 (1.06–15.12)	2.20 (0.82–5.89)	1.21 (0.59–2.49)
Lower three wealth quintiles	2.37 (1.27–4.44)	1.56 (0.99–2.46)	1.06 (0.54–2.07)
Did not complete primary school	2.58 (1.52–4.36)	1.32 (0.72–2.43)	0.79 (0.51–1.23)
Cannot read	1.02 (0.66–1.57)	0.91 (0.56–1.48)	0.44 (0.20–0.98)
Unimproved primary water source	1.10 (0.41–2.98)	1.48 (0.55–3.99)	1.04 (0.47–2.31)
Primary water source not from tap	3.48 (1.09–11.09)	2.24 (0.73–6.83)	1.14 (0.60–2.19)
Program characteristics			
Three or more antenatal clinic visits	0.78 (0.38–1.59)	1.51 (0.88–2.57)	1.01 (0.40–2.54)
Obtained all three hygiene kit refills	4.09 (1.94–8.63)	1.54 (0.77–3.07)	1.54 (0.84–2.82)
Number of home visits by HSA*			
3 vs. ≤ 2	3.04 (1.26–7.31)	1.26 (0.58–2.73)	1.93 (0.94–3.99)
4 vs. ≤ 2	3.64 (1.41–9.44)	1.08 (0.46–2.54)	2.64 (1.16–6.03)
≥ 5 vs. ≤ 2	9.32 (3.56–24.38)	3.90 (1.07–14.21)	3.82 (1.37–10.60)

*aOR = adjusted odds ratio estimated by a bivariate logistic regression model controlling for district and accounting for clustering by health facility; CI = confidence interval; HSA = Health Surveillance Assistants.

†N represents respondents who did not exhibit the behavior of interest at baseline.

of disease attributable to water treatment and improved hygiene.

DISCUSSION

This evaluation showed that the integration of water treatment and handwashing products and promotion into 15 health facilities included in Malawi's antenatal care system was an effective approach for changing hygiene behaviors among expectant mothers. Program participants exhibited statistically significant increases in a number of water treatment indicators, including water treatment with any method, awareness of WaterGuard, knowledge of proper use of WaterGuard, reported WaterGuard use in the previous 2 days, WaterGuard use in the home confirmed by the presence of residual chlorine in stored water, and WaterGuard purchase and use after exhausting their free bottles (suggesting that some women sustained water treatment behaviors). Use of the hygiene kit bucket was also observed in over 90% of homes at follow-up, and over 50% of participants reported removing water by pouring or using a tap, thereby reducing the risk of recontamination of stored water by hands or other objects.^{6,15} Finally, we observed increases in the presence of soap in respondents' homes and the ability of mothers to demonstrate correct handwashing procedures. Because household water treatment, safe water storage, and handwashing with soap have all been shown to reduce the risk of diarrhea by ~30–40%, we expect that participants in this program and their families experienced a positive health benefit.^{3–5,16–18} Additionally, maternal handwashing at the time of delivery has been associated with reduced neonatal mortality, suggesting additional protective benefits of this intervention.¹⁹

There are several explanations for the success of this program in changing maternal hygiene behaviors. First, this program involved water treatment and hand hygiene promotion both at the clinic and in the home. When asked who gave them the most confidence to use WaterGuard, the majority of women named health care providers or HSAs, which is consistent with previous research suggesting that health care personnel are trusted sources of information and health facilities are effective venues for promoting these behaviors.¹¹ Furthermore,

at least three previous studies have documented greater adoption of point-of-use water treatment in populations receiving one-on-one interventions in the home.^{20–22} In this study, both confirmed WaterGuard use and correct handwashing were associated with increased HSA home visits; however, because the study was not designed to assess the effect of HSA visits, this association may have been confounded by other factors. Second, the intervention used behavior change strategies at multiple levels, including mass media promotion by PSI, clinic-based education, government engagement through the Ministry of Health, and interpersonal communication by HSAs and between women.^{23,24} Finally, four of five characteristics that influence diffusion of innovations were present: advantage over alternatives (e.g., boiling, which is more expensive and time-consuming^{25,26}), compatibility with existing needs, low complexity, and trialability.²⁷ We did not assess the fifth characteristic, observability of results.

In this evaluation, among participants who did not use WaterGuard at baseline, confirmed use of WaterGuard at follow-up was associated with rural residence, lower wealth, and lower education. These results contrasted with the tendency, found in a previous nationwide survey, for WaterGuard use in Malawi to be highest in urban, more educated, and wealthier populations, suggesting that this type of program may be particularly successful in reaching poor, uneducated, and rural populations that have greatest risk of adverse outcomes from diarrheal illness.^{9,28}

The cost per program beneficiary, which was estimated to be US\$ 5.63, was relatively low even though we did not take into account potential cost savings from water treatment or handwashing with soap. The cost of this program was comparable to the cost of an insecticide-treated bednet distribution program which, in one study, was estimated to be US\$ 1.40 per person protected per year, including potential cost savings.²⁹ Studies of the persistence of water treatment and handwashing behaviors over time are needed to assess costs per sustained program benefit.

Use of perinatal services reported in this evaluation was higher than described in the population-based 2006 Malawi Multiple Indicator Cluster Survey (MICS), including institutional delivery in Blantyre (90% versus 76%) and Salima (59%

versus 44%) and postnatal checks in Blantyre (68% versus 45%) and Salima (37% versus 28%).² Although the population surveyed in this evaluation may not be directly compared with the MICS survey population, and we do not know whether districtwide increases in use of these services occurred between 2006 and 2008, offering incentives for antenatal clinic attendance may have increased use of services, as was seen previously in Malawi with immunization services.³⁰

This study had several limitations. First, because women from more distant areas may have been less likely to attend antenatal clinic and the program was implemented in only 15 health facilities, the program population may not be representative of the entire population in these districts. Second, participation in the evaluation may have influenced the participants' behavior. Third, the population lost to follow-up was wealthier, more educated, and more likely to live in an urban area than the follow-up evaluation population. Improvements in water treatment and hand hygiene practices among participants with similar demographics who remained in the evaluation suggest that the loss to follow-up of these women would not have significantly affected evaluation findings. Fourth, the baseline survey was conducted during the dry season, whereas the follow-up survey was conducted during the rainy season. Seasonal variation may have affected water treatment behaviors. Fifth, factors outside of this intervention could have also contributed to improved water treatment and hygiene behaviors over time in the surveyed population. Finally, because of resource limitations, this project was limited to 1 year. Because previous studies of point-of-use chlorine water treatment programs have suggested that there is attenuation in health impact over time,¹⁸ it would be particularly useful for future evaluations of this program to take place after periods of 1 or more years to measure the extent to which new hygiene behaviors were sustained.

Results of this evaluation suggest that integrated interventions offer promising opportunities for more efficient and effective health service delivery in resource-poor settings. The significant improvements in water treatment, hand hygiene, and perinatal care demonstrated in this program justify consideration of further implementation, along with program evaluation to assure that objectives are being met, in other parts of Malawi and other countries where contaminated drinking water and poor hygiene contribute to disease and death.

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Note: Supplemental table appears at www.ajtmh.org.

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REFERENCES

1. Parashar UD, Bresee JS, Glass RI, 2003. The global burden of diarrhoeal disease in children. *Bull World Health Organ* 81: 236.
2. National Statistical Office and UNICEF, 2008. Malawi Multiple Indicator Cluster Survey 2006, Final Report. Lilongwe, Malawi: National Statistical Office and UNICEF. Available at: http://www.childinfo.org/files/MICS3_Malawi_FinalReport_2006_eng.pdf. Accessed March 14, 2010.
3. Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM Jr, 2005. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis* 5: 42–53.
4. Clasen T, Schmidt WP, Rabie T, Roberts I, Cairncross S, 2007. Interventions to improve water quality for preventing diarrhoea: systemic review and meta-analysis. *BMJ* 334: 755–756.
5. Curtis V, Cairncross S, 2003. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect Dis* 3: 275–281.
6. Hammad ZH, Dirar HA, 1982. Microbiological examination of sebel water. *Appl Environ Microbiol* 43: 1238–1243.
7. Han AM, Oo KN, Midorikawa Y, Shwe S, 1989. Contamination of drinking water during collection and storage. *Trop Geogr Med* 41: 138–140.
8. Kramer MS, Kakuma R, 2002. Optimal duration of exclusive breastfeeding. *Cochrane Database Syst Rev* CD003517.
9. Stockman LJ, Fischer TK, Deming M, Ngwira B, Quick RE, 2007. Point-of-use water treatment and use among mothers in Malawi. *Emerg Infect Dis* 13: 1077–1080.
10. Bryce J, Daelmans B, Dwivedi A, Fauveau V, Lawn JE, Mason E, Newby H, Shankar A, Starrs A, Wardlaw T, 2008. Countdown to 2015 for maternal, newborn, and child survival: the 2008 report on tracking coverage of interventions. *Lancet* 371: 1247–1258.
11. Parker AA, Stephenson R, Riley PL, Ombeki S, Komolleh C, Sibley L, Quick R, 2006. Sustained high levels of stored drinking water treatment and retention of hand-washing knowledge in rural Kenyan households following a clinic-based intervention. *Epidemiol Infect* 134: 1029–1036.
12. Blanton E, Ombeki S, Oluoch GO, Mwaki A, Wannemuehler K, Quick R, 2010. Evaluation of the role of school children in the promotion of point-of-use water treatment and handwashing in schools and households—Nyanza Province, Western Kenya, 2007. *Am J Trop Med Hyg* 82: 664–671.
13. Filmer D, Pritchett LH, 2001. Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. *Demography* 38: 115–132.
14. Eliasziw M, Donner A, 1991. Application of the McNemar test to non-independent matched pair data. *Stat Med* 10: 1981–1991.
15. Mintz ED, Reiff FM, Tauxe TV, 1995. Safe water treatment and storage in the home: a practical new strategy to prevent waterborne disease. *JAMA* 273: 948–953.
16. Tuttle J, Ries AA, Chimba RM, Perera CU, Bean NH, Griffin PM, 1995. Antimicrobial-resistant epidemic *Shigella dysenteriae* type 1 in Zambia: modes of transmission. *J Infect Dis* 171: 371–375.
17. Roberts L, Chartier Y, Chartier O, Malenga G, Toole M, Rodka H, 2001. Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial. *Bull World Health Organ* 79: 280–287.
18. Arnold BF, Colford JM, 2007. Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: a systemic review and meta-analysis. *Am J Trop Med Hyg* 76: 354–364.
19. Rhee V, Mullaly LC, Khatry S, Katz J, LeClerq SC, Darmstadt GL, Tielsch JM, 2008. Maternal and birth attendant hand washing and neonatal mortality in southern Nepal. *Arch Mediatr Adolesc Med* 162: 603–608.
20. Thevos A, Olsen S, Rangel J, Kaona F, Tembo M, Quick R, 2002–2003. Social marketing and motivational interviewing as community interventions for safe water behaviors: follow-up surveys in Zambia. *Int Q Community Health Educ* 21: 51–65.

21. Dunston C, McAfee D, Kasier R, Rakotoarison D, Rambeloson L, Hoang AT, Quick RE, 2001. Collaboration, cholera, and cyclones: a project to improve point-of-use water quality in Madagascar. *Am J Public Health* 91: 1574–1576.
22. Makutsa P, Nzaku K, Ogutu P, Barasa P, Ombeki S, Mwaki A, Garrett V, Quick R, 2001. Challenges in the implementation of a socially-marketed point-of-use water treatment and safe storage intervention in rural western Kenya. *Am J Public Health* 91: 1571–1573.
23. Institute of Medicine, Health and Behavior, 2001: *The Interplay of Biological, Behavioral and Societal Influences*. Washington, DC: Academy Press.
24. McLeroy KR, Bibeau D, Steckler A, Glanz K, 1988. An ecological perspective on health promotion programs. *Health Educ Q* 15: 351–377.
25. Gilman RH, Skillicorn P, 1985. Boiling of drinking-water: can a fuel-scarce community afford it? *Bull World Health Organ* 63: 157–163.
26. Biran A, Abbot J, Mace R, 2004. Families and firewood: the costs and benefits of children in firewood collection and use in two rural communities in sub-Saharan Africa. *Hum Ecol* 32: 1–25.
27. Rogers EM, 1995: *Diffusion of Innovations*, Fourth edition. New York: The Free Press.
28. Victora CG, Wagstaff A, Schellenberg JA, Gwatkin D, Claeson M, Habicht J, 2003. Applying an equity lens to child health and mortality: more of the same is not enough. *Lancet* 362: 233–241.
29. Wiseman V, Hawley WA, ter Kuile FO, Phillips-Howard PA, Vulule JM, Nahlen BL, Mills AJ, 2003. The cost-effectiveness of permethrin-treated bed nets in an area of intense malaria transmission in western Kenya. *Am J Trop Med Hyg* 68 (Suppl 4): 161–167.
30. Mathanga DP, Luman ET, Campbell CH, Silwimba C, Malenga G, 2009. Integration of insecticide-treated net distribution into routine immunization services in Malawi: a pilot study. *Trop Med Int Health* 14: 792–801.