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Long-term Impact of Integration of Household Water Treatment and Hygiene Promotion with Antenatal Services on Maternal Water Treatment and Hygiene Practices in Malawi

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Abstract. A clinic-based program to integrate antenatal services with distribution of hygiene kits including safe water storage containers, water treatment solution (brand name *WaterGuard*), soap, and hygiene education, was implemented in Malawi in 2007 and evaluated in 2010. We surveyed 389 participants at baseline in 2007, and found and surveyed 232 (60%) participants to assess water treatment, test stored drinking water for residual chlorine (an objective measure of treatment), and observe handwashing technique at follow-up in 2010. Program participants were more likely to know correct water treatment procedures (67% versus 36%; $P < 0.0001$), treat drinking water with *WaterGuard* (24% versus 2%; $P < 0.0001$), purchase and use *WaterGuard* (21% versus 1%; $P < 0.001$), and demonstrate correct handwashing technique (50% versus 21%; $P < 0.001$) at the three-year follow-up survey than at baseline. This antenatal-clinic-based program may have contributed to sustained water treatment and proper handwashing technique among program participants.

INTRODUCTION

Diarrheal diseases are a leading cause of mortality for children less than five years of age in developing countries.[1] Practices that have been shown to reduce diarrheal diseases include household treatment and safe storage of drinking water,[2] proper handwashing with soap,[3] and improved sanitation.[4] To reduce the risk of diarrhea in Malawi, a household water treatment product (brand name *WaterGuard*) was launched in 2002 by the nongovernmental organization (Population Services International, Washington, DC). A 2005 survey in Malawi showed that although 65% of mothers had heard of *WaterGuard*, reported current use was 7%.[5] In an effort to increase use of *WaterGuard*, a program that integrated point-of-use water treatment with *WaterGuard* and hygiene promotion with antenatal care services for pregnant women was implemented in Malawi in 2007.[6] An important component of this program was maternal education during pregnancy when women may be more concerned about the health of their babies.[7]

In this program, 15,000 pregnant women in 2 districts of Malawi received free hygiene kits (consisting of a water storage container with a tap, a bottle of locally-produced water treatment product with the brand-name *WaterGuard*, a bar of soap, and two sachets of oral rehydration salts) during their first antenatal clinic visit after program implementation in May 2007, and up to three free refills of *WaterGuard* and soap during subsequent antenatal visits, at delivery, or during postnatal checkups (Figure 1). An evaluation in 2008 showed that program participants were more likely to know how to correctly use *WaterGuard* (62% versus 27%; $P < 0.0001$), to demonstrate confirmed *WaterGuard* use (61% versus 1%; $P < 0.0001$), to purchase and use *WaterGuard* in the home (32% versus 1%; $P < 0.0001$), and to demonstrate correct handwashing technique with soap (68% versus 22%; $P < 0.0001$).[6] Friends and relatives of program participants, who had not received any free products, also demonstrated increased knowledge of water treatment procedure with *WaterGuard*, purchase and use of *WaterGuard*, and correct handwashing technique, suggesting that these behaviors had diffused to participants' close contacts.[8]

Although the formal program ended in 2008, many nurses and health surveillance assistants (HSAs) continued promoting safe water and handwashing as part of their ongoing patient and community education activities. The *WaterGuard* social marketing program continued in Malawi, although annual sales increases were modest, with an average increase of approximately 58,000 bottles per year, or approximately 0.03 bottles per household. In addition, the Ministry of Health continued a program in which a free chlorine stock solution was distributed during the rainy season through HSAs at the local level.

We evaluated this integrated antenatal clinic program in 2010, 3 years after program initiation and 2 years after hygiene kit distribution ended to assess the sustainability of program impact on behaviors of participants and their relatives/friends.

MATERIALS AND METHODS

Evaluation design and baseline data collection. We performed a three-year follow-up cross-sectional survey of the same program participants and their relatives or friends enrolled in the original evaluation. As described by Sheth and others,[6] our target sample was 400 program participants, based on assumptions of 7% overall use of *WaterGuard* at baseline, 14% at follow-up, type I error of 5%, power of 80%, and 20% loss to follow-up. Program participants were initially enrolled in April–May 2007 by selecting a weighted sample of pregnant women from each of the 15 health facilities proportional to the average monthly antenatal clinic attendance. Enrolled pregnant women were asked to identify relatives or friends with children less than five years of age living in the same village, and we included one relative or friend for each pregnant woman in the evaluation.[6] In 2007 during the dry season, we conducted a baseline cross-sectional survey of 389 newly enrolled pregnant female program participants receiving care at 15 antenatal clinics, and 386 of their female relatives or friends with children less than five years of age in Blantyre and Salima Districts. The hygiene kits were distributed at the time of the baseline survey, refills of *WaterGuard* and soap were offered to program participants

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

at up to three additional visits, and a follow-up cross-sectional survey was conducted in 2008, 9 months later during the rainy season. The Ministry of Health Malawi also has a program to occasionally distribute a free 1% chlorine stock solution that is prepared at the local level by HSAs. We were unable to ascertain either a geographic or temporal pattern of this product distribution.

Follow-up data collection. For the 2010 follow-up survey, which also took place in the rainy season, district and local public health officers helped field workers locate program participants. The survey was administered at the household level by trained enumerators who spoke Chichewa and English, and included only women interviewed in the baseline survey. The interviewer administered a questionnaire on demographic and socioeconomic characteristics; health of the child; subsequent pregnancies; water sources, storage, and treatment; hygiene and sanitation practices; and observations of the water storage container, water treatment method, presence of soap, presence of a handwashing station, and demonstration of handwashing procedure. Stored water was also tested for residual chlorine using the N, N-diethyl-*p*-phenylenediamine method (www.hach.com) as an objective measure of use of *WaterGuard* or chlorine stock solution. The questionnaire for relatives or friends was similar to the one used for program participants; questions specific to the antenatal clinic program were removed.

Human subjects protection. The Centers for Disease Control and Prevention Institutional Review Board 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 by using SAS version 9.2 (SAS Institute, Cary, NC).

Primary outcomes of interest included knowledge of water treatment procedures with *WaterGuard*, detectable residual chlorine in stored drinking water, confirmed use of *WaterGuard* (defined as presence of a bottle of *WaterGuard* and detectable residual chlorine in stored water), reported purchase and confirmed use of *WaterGuard*, and use of proper handwashing technique (lathering hands completely with soap during a handwashing demonstration).

To investigate overall loss to follow-up, we assessed missing persons at the health facility level, village level classification, and across various demographic characteristics to determine if any patterns existed.

Measurement of primary indicators was summarized at the health facility level for paired analysis to identify changes from baseline to the three-year follow-up. An exact test of a binomial proportion was used to statistically assess whether the proportion of clinics that demonstrated improvement was greater than what would be expected because of chance. Because of intangible differences between clinics that could affect outcomes at individual health facilities, we conducted the statistical comparison at the health facility level. Because

TABLE 1
Enrolled participants and relatives/friends at baseline (2007) found at 3-year follow-up (2010), by health facility, Malawi

District	Health facility	No. participants at baseline	% Of participants living in rural area	No. (%) participants at 3-year follow-up	No. friends/relatives at baseline	No. (%) friends/relatives at 3-year follow-up
Blantyre	1	23	96	13 (57)	23	7 (30)
	2	66	14	32 (48)	66	14 (21)
	3	31	3	13 (42)	31	8 (26)
	4	14	100	13 (93)	14	9 (64)
	5	22	100	12 (55)	22	10 (45)
	6	41	12	23 (56)	41	15 (37)
	7	21	100	12 (57)	20	8 (40)
	8	13	100	8 (62)	13	11 (85)
Blantyre total		231	46	126 (55)	230	82 (36)
Salima	9	11	100	5 (45)	11	7 (64)
	10	30	100	24 (80)	28	20 (71)
	11	11	100	5 (45)	11	9 (82)
	12	17	100	16 (94)	17	8 (47)
	13	11	100	9 (82)	11	4 (36)
	14	27	100	15 (56)	27	12 (44)
	15	51	78	32 (63)	51	26 (51)
Salima total		158	93	106 (67)	156	86 (55)
Total		389	65	232 (60)	386	168 (44)

TABLE 2
Demographic characteristics of program participants at baseline (2007) and three-year follow-up (2010), Blantyre and Salima Districts, Malawi*

Characteristic	Blantyre District		Salima District		Total	
	Baseline, n = 231	Follow-up, n = 126	Baseline, n = 158	Follow-up, n = 106	Baseline, n = 389	Follow-up, n = 232
Median age (range)	23 (15–41)	27 (17–45)	24 (16–45)	26 (19–45)	23 (15–45)	26 (17–45)
Median household size (range)	4 (1–10)	5 (1–10)	4 (2–9)	5 (2–11)	4 (1–10)	5 (1–11)
Median no. children < 5 years of age (range)	1 (0–4)	1 (0–4)	1 (0–3)	1 (0–5)	1 (0–4)	1 (0–5)
Rural	107 (46)	67 (54)	147 (93)	92 (87)	254 (65)	159 (69)
Urban	124 (54)	57 (46)	11 (7)	14 (13)	135 (35)	71 (31)
Marital status						
Married	216 (94)	111 (89)	155 (98)	96 (91)	371 (95)	207 (90)
Single	12 (5)	7 (6)	3 (2)	1 (1)	15 (4)	8 (3)
Separated	3 (1)	7 (6)	0 (0)	8 (8)	3 (1)	15 (6)
Widowed	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (0)
Education						
None	18 (8)	9 (7)	55 (35)	29 (27)	73 (19)	38 (17)
Some primary school	112 (49)	60 (48)	79 (50)	59 (56)	191 (49)	119 (52)
Completed primary school	36 (16)	24 (19)	13 (8)	10 (9)	49 (13)	34 (15)
More than primary school	63 (28)	31 (25)	11 (7)	8 (8)	74 (19)	39 (17)
Able to read	178 (78)	NA	70 (44)	NA	248 (64)	NA

*Values are no. (%) unless otherwise indicated. For some items, values may vary. NA = not available.

of high loss to follow-up, we examined data at the health facility level to assess for a worst-case scenario; in this analysis we assumed all participants or relatives/friends lost to follow-up did not have knowledge of water treatment procedures with *WaterGuard*, detectable residual chlorine in stored drinking water, confirmed use of *WaterGuard*, reported purchase and confirmed use of *WaterGuard*, or use of proper handwashing technique.

RESULTS

Enrollment. During program implementation, we enrolled 231 pregnant women (participants) from 8 health facilities and 230 relatives/friends in Blantyre District at baseline, and 158 pregnant women (participants) from 7 health facilities and 156 relatives/friends in Salima District in the baseline survey.[6] We found and interviewed 182 (79%) original participants in Blantyre and 148 (94%) original participants in Salima at follow-up in 2008.[6] We found and interviewed 155 (67%) original relatives/friends in Blantyre and 120 (77%) original relatives/friends in Salima at follow-up in 2008.[8]

We found and interviewed 126 (55%) original participants in Blantyre and 106 (67%) original participants in Salima at follow-up in 2010. We found and interviewed 82 (36%) original relatives/friends in Blantyre and 86 (55%) original relatives/friends in Salima at follow-up in 2010.

Loss to follow-up. The median percentage of participants present at the 2010 follow-up by health facility was 57% (range = 42–94%). Health facilities serving a predominantly urban population had greater dropout percentages than health facilities serving only rural populations (Table 1).

Demographic and socioeconomic characteristics. The median age of participants at baseline was 24 years (range = 15–45 years); 95% were married (Table 2). At follow-up in 2010, the median age was 26 years (range = 17–45 years) and 90% were married. Of participants present at follow-up, 38

TABLE 3
Water source, water handling, and water treatment practices reported by program participants or observed by field workers at baseline (2007) and three-year follow-up (2010), Blantyre and Salima Districts, Malawi*

Characteristic	Blantyre District		Salima District		Total	
	Baseline, n = 231	Follow-up, n = 126	Baseline, n = 158	Follow-up, n = 106	Baseline, n = 389	Follow-up, n = 232
Primary water source†						
Improved water source	213 (92)	119 (94)	133 (84)	94 (89)	346 (89)	213 (92)
House/yard tap, public tap	120 (52)	57 (45)	14 (9)	6 (6)	134 (34)	63 (27)
Protected borehole, well, or spring	93 (40)	62 (49)	119 (75)	88 (83)	212 (54)	150 (65)
Water storage and handling†						
Water storage container has a cover	218 (94)	111 (90)	141 (92)	96 (92)	359 (93)	207 (91)
Hygiene kit bucket used for water storage	NA	66 (53)	NA	39 (37)	NA	105 (45)
Pours or uses tap to remove drinking water	10 (4)	65 (52)	0 (0)	34 (32)	1 (3)	99 (42)
Water treatment‡						
Treats drinking water with any method	205 (89)	113 (90)	130 (82)	101 (96)	335 (86)	214 (93)
WaterGuard	124 (54)	82 (35)	46 (29)	79 (75)	170 (44)	161 (69)
Boiling	86 (37)	16 (13)	48 (30)	22 (21)	134 (34)	38 (16)
Treat with chlorine stock solution	22 (10)	53 (42)	27 (17)	56 (53)	49 (13)	109 (47)
Handwashing†						
Soap in household	179 (78)	101 (80)	105 (68)	68 (64)	284 (74)	169 (73)
Presence of handwashing station with soap and water	30 (13)	25 (20)	23 (15)	67 (63)	53 (14)	92 (40)

*Values are no. (%). NA = not available.
†Characteristics observed by field workers.
‡Characteristics reported by participant.

TABLE 4

Percentage of program participants and relatives/friends exhibiting knowledge and confirmed use of *WaterGuard*, and able to demonstrate proper handwashing technique, at baseline (2007), nine-month follow-up (2008), and three-year follow-up (2010), by district, Malawi*

Characteristic	Blantyre District			Salima District			Total		
	Participants								
	Baseline 2007, n = 231	Follow-up 2008, n = 182	Follow-up 2010, n = 126	Baseline 2007, n = 158	Follow-up 2008, n = 148	Follow-up 2010, n = 106	Baseline 2007, n = 389	Follow-up 2008, n = 330	Follow-up 2010, n = 232
Knows how to use *WaterGuard*	98 (42)	109 (60)	85 (67)	41 (26)	95 (65)	70 (66)	139 (36)	204 (62)	155 (67)
Positive chlorine residual in drinking water	27 (12)	98 (57)	48 (38)	7 (4)	125 (86)	69 (65)	34 (9)	223 (71)	117 (54)
Observed *WaterGuard* use (observed *WaterGuard* in home and positive chlorine test result)	4 (2)	76 (44)	25 (20)	2 (1)	118 (81)	31 (29)	6 (2)	194 (61)	56 (24)
Purchase (reported *WaterGuard* purchase, observed *WaterGuard*, and positive chlorine test result)	4 (2)	45 (27)	21 (17)	0 (0)	55 (39)	28 (26)	4 (1)	100 (32)	49 (21)
Handwashing: lathers hands completely with soap	47 (20)	117 (64)	66 (52)	34 (22)	107 (72)	49 (46)	81 (21)	224 (68)	115 (50)
	Relatives/friends								
	Baseline 2007, n = 230	Follow-up 2008, n = 155	Follow-up 2010, n = 82	Baseline 2007, n = 156	Follow-up 2008, n = 120	Follow-up 2010, n = 86	Baseline 2007, n = 386	Follow-up 2008, n = 275	Follow-up 2010, n = 168
Knows how to use *WaterGuard*	91 (40)	68 (47)	37 (45)	42 (27)	49 (53)	43 (50)	132 (34)	117 (50)	80 (48)
Positive chlorine residual in drinking water	28 (12)	40 (28)	20 (24)	4 (3)	53 (52)	45 (52)	32 (9)	93 (38)	65 (43)
Observed *WaterGuard* use (observed *WaterGuard* in home and positive chlorine test result)	8 (3)	26 (18)	9 (11)	1 (1)	34 (28)	18 (21)	9 (2)	60 (25)	27 (16)
Purchase (reported *WaterGuard* purchase, observed *WaterGuard*, and positive chlorine test result)	6 (3)	25 (17)	7 (9)	0 (0)	34 (28)	17 (20)	6 (2)	59 (21)	24 (14)
Handwashing: lathers hands completely with soap	45 (20)	88 (57)	34 (41)	20 (13)	72 (64)	29 (34)	65 (17)	160 (60)	63 (38)

*Values are no. (%).

TABLE 5

Percentage of program participants exhibiting knowledge and confirmed use of *WaterGuard*, and able to demonstrate proper handwashing technique, at baseline (2007) and 3-year follow-up (2010), by health facility, Malawi*

District	Clinic	Participants enrolled at baseline	Available at follow-up	Knows how to use *WaterGuard*		Positive chlorine residual in drinking water		Observed *WaterGuard* use (*WaterGuard* and positive chlorine test result)		Observed *WaterGuard* purchase (purchased *WaterGuard*, positive chlorine test result, and *WaterGuard* observed)		Handwashing: lathers hands completely with soap	
				Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010
Total		389	232 (60)	139 (36)	155 (67)	34 (9)	117 (54)	6 (2)	56 (24)	4 (1)	49 (21)	81 (21)	115 (50)
Blantyre	1	23	13 (57)	5 (22)	6 (46)	3 (13)	3 (23)	0 (0)	1 (8)	0 (0)	1 (8)	1 (4)	6 (46)
	2	66	32 (48)	31 (47)	17 (53)	19 (29)	12 (38)	4 (6)	3 (9)	4 (6)	1 (3)	25 (38)	20 (63)
	3	31	13 (42)	13 (42)	11 (85)	0 (0)	6 (46)	0 (0)	6 (46)	0 (0)	6 (46)	7 (23)	5 (38)
	4	14	13 (93)	5 (36)	10 (77)	0 (0)	3 (23)	0 (0)	1 (8)	0 (0)	1 (8)	1 (7)	5 (38)
	5	22	12 (55)	8 (36)	10 (83)	1 (5)	9 (75)	0 (0)	4 (33)	0 (0)	3 (25)	2 (9)	7 (58)
	6	41	23 (56)	22 (54)	15 (65)	0 (0)	5 (22)	0 (0)	1 (4)	0 (0)	1 (4)	5 (12)	16 (70)
	7	21	12 (57)	11 (52)	10 (83)	3 (14)	8 (67)	0 (0)	7 (58)	0 (0)	6 (50)	3 (14)	4 (33)
	8	13	8 (62)	3 (23)	6 (75)	1 (8)	2 (25)	0 (0)	2 (25)	0 (0)	2 (25)	3 (23)	3 (38)
Salima	9	11	5 (45)	0 (0)	3 (60)	0 (0)	4 (80)	0 (0)	3 (60)	0 (0)	2 (40)	0 (0)	3 (60)
	10	30	24 (80)	2 (7)	18 (75)	1 (3)	12 (50)	0 (0)	3 (13)	0 (0)	2 (8)	8 (27)	6 (25)
	11	11	5 (45)	3 (27)	4 (80)	0 (0)	5 (100)	0 (0)	1 (20)	0 (0)	1 (20)	1 (9)	4 (80)
	12	17	16 (94)	4 (24)	8 (50)	2 (12)	14 (88)	1 (6)	7 (44)	0 (0)	7 (44)	4 (24)	6 (38)
	13	11	9 (82)	2 (18)	6 (67)	0 (0)	4 (44)	0 (0)	1 (11)	0 (0)	1 (11)	1 (9)	4 (44)
	14	27	15 (56)	8 (30)	10 (67)	3 (11)	12 (80)	1 (4)	8 (53)	0 (0)	8 (53)	7 (26)	9 (60)
	15	51	32 (63)	22 (43)	21 (66)	1 (2)	18 (56)	0 (0)	8 (25)	0 (0)	7 (22)	13 (25)	17 (53)
P for clinic-level analysis†				< 0.0001		< 0.0001		< 0.0001		< 0.001		< 0.001	

*Values are no. (%).
†Baseline and three-year follow-up results were compared by using exact test of binomial proportions.

(17%) reported having no education, 119 (52%) had some primary school, and 73 (32%) had completed primary school. The median household size was 5 persons (range = 1–11 persons) with a median of one child less than five years of age (range = 0–5 persons).

Water source, storage, and treatment among participants. Primary water sources and the practice of storing water in the home did not change between baseline and follow-up evaluations among participants (Table 3). Continued use of the hygiene kit container provided at enrollment in 2007 was observed during the 2010 evaluation among 53% of Blantyre participants and 37% of Salima participants. The reasons for stopping use of the hygiene kit container included broken (91%), stolen (3%), kept water temperature too high (2%), and used for other purposes (5%).

Although the proportion of participants who reported treating their stored household drinking water did not change from baseline to the 2010 follow-up, the treatment methods changed (Table 3). At baseline, 34% of participants reported boiling water compared with 16% at follow-up in 2010. From baseline to 2010 follow-up, participants reported an increase in use of *WaterGuard* (44 to 69%) and chlorine stock solution (13 to 47%).

***WaterGuard* knowledge and use among participants.** Knowledge of the correct *WaterGuard* water treatment procedure increased for participants from baseline in 2007 (36%) to follow-up in 2008 (62%) and 2010 (67%) (Table 4 and Table 5). Detectable chlorine residual in stored water increased among participants from baseline (9%) to follow-up (54%). Confirmed *WaterGuard* use among participants, increased from 2% at baseline to 24% at 2010 follow-up. Purchase and confirmed use of *WaterGuard* increased from 1% at baseline to 24% at follow-up. To our knowledge, program participants had not received any free *WaterGuard* bottles after their third refill at the clinic where they were enrolled.

At the health facility level, we found that knowledge of correct *WaterGuard* procedure, detectable chlorine residual, and confirmed *WaterGuard* use increased among participants at all 15 health facilities from baseline to three-year follow-up ($P < 0.0001$) (Table 5). Confirmed *WaterGuard* use and purchase improved among participants at 14 (93%) of 15 health facilities ($P < 0.001$) (Table 5). In an analysis of the worst case scenario for lost-to-follow-up participants, detectable chlorine residual, confirmed *WaterGuard* use, and confirmed *WaterGuard* use and purchase remained statistically significant ($P < 0.01$) from baseline to three-year follow-up.

Of 104 (45%) participants who reported not using *WaterGuard*, reasons included reported use of chlorine stock solution given free by the Ministry of Health (47%), inability to afford *WaterGuard* (36%), not receiving free *WaterGuard* bottles from the health facility (17%), *WaterGuard* not being available for purchase (5%), and the belief that their water was clean and therefore did not need *WaterGuard* (10%).

Hand hygiene. Observed soap in the home did not change significantly between baseline and 2010 follow-up surveys. However, correct handwashing technique (using soap and lathering thoroughly) increased from 21% at baseline to 50% at follow-up (Table 5). Ability to demonstrate correct handwashing technique increased among participants across 14 (93%) of 15 health facilities ($P < 0.001$).

Relatives and friends. From baseline to 2010 follow-up, there was an increase among relatives/friends of participants

TABLE 6

Percentage of relatives/friends of antenatal program participants exhibiting knowledge and confirmed use of *WaterGuard*, and able to demonstrate proper handwashing technique at baseline (2007) and three-year follow-up (2010), by health facility, Malawi*

District	Clinic	Relatives or friends enrolled at baseline	Available at follow-up	Knows how to use *WaterGuard*		Positive chlorine residual in drinking water		Observed *WaterGuard* use (*WaterGuard* and positive chlorine test result)		Observed *WaterGuard* purchase (purchased *WaterGuard*, positive chlorine test result, *WaterGuard* observed)		Handwashing: lathers hands completely with soap	
				Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010	Baseline 2007	Follow-up 2010
Total		386	168 (44)	132 (34)	80 (48)	32 (9)	65 (43)	9 (2)	27 (16)	9 (2)	24 (14)	65 (17)	63 (38)
Blantyre	1	23	7 (30)	5 (22)	1 (14)	3 (13)	1 (14)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	3 (43)
	2	66	14 (21)	26 (39)	5 (36)	17 (26)	5 (36)	3 (5)	1 (7)	2 (3)	1 (7)	21 (32)	7 (50)
	3	31	8 (26)	10 (32)	5 (63)	4 (13)	2 (25)	3 (10)	1 (13)	3 (10)	1 (13)	5 (16)	0 (0)
	4	14	9 (64)	6 (43)	7 (78)	0 (0)	3 (33)	0 (0)	1 (11)	0 (0)	0 (0)	3 (21)	5 (56)
	5	22	10 (45)	6 (27)	5 (50)	0 (0)	4 (40)	0 (0)	3 (30)	0 (0)	2 (20)	3 (14)	7 (70)
	6	41	15 (37)	24 (59)	6 (40)	1 (2)	2 (13)	1 (2)	0 (0)	0 (0)	0 (0)	9 (22)	7 (47)
	7	20	8 (40)	11 (55)	5 (63)	3 (15)	3 (38)	1 (5)	3 (38)	1 (5)	3 (38)	1 (5)	3 (38)
	8	13	11 (85)	2 (15)	3 (27)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (15)	2 (18)
Salima	9	11	7 (64)	0 (0)	5 (71)	0 (0)	2 (29)	0 (0)	2 (29)	0 (0)	2 (29)	1 (9)	4 (57)
	10	28	20 (71)	5 (18)	12 (60)	0 (0)	7 (35)	0 (0)	2 (10)	0 (0)	1 (5)	6 (21)	5 (25)
	11	11	9 (82)	3 (27)	3 (33)	0 (0)	3 (33)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (11)
	12	17	8 (47)	3 (18)	5 (63)	1 (6)	6 (75)	0 (0)	3 (38)	0 (0)	3 (38)	2 (12)	5 (63)
	13	11	4 (36)	1 (9)	3 (75)	0 (0)	3 (75)	0 (0)	1 (25)	0 (0)	1 (25)	0 (0)	1 (25)
	14	27	12 (44)	14 (52)	7 (58)	0 (0)	9 (75)	0 (0)	5 (42)	0 (0)	5 (42)	5 (19)	5 (42)
	15	51	26 (51)	16 (31)	8 (31)	3 (6)	15 (58)	1 (2)	5 (19)	0 (0)	5 (19)	6 (12)	8 (31)
P for clinic-level analysis†				0.06		< 0.001		0.06		0.2		< 0.001	

* Values are no. (%).
† Baseline and three-year follow-up results were compared by using exact test of binomial proportions.

in detectable chlorine residual in stored drinking water samples (9% versus 43%), confirmed *WaterGuard* use (2% versus 16%), reported purchase and confirmed *WaterGuard* use (2% versus 14%), and the ability to demonstrate correct handwashing technique (17% versus 38%) (Table 6).

Detectable chlorine residual in household stored drinking water and the ability to demonstrate correct handwashing technique increased among relatives/friends across 14 (93%) of 15 health facilities ($P < 0.001$) (Table 6). Confirmed use of *WaterGuard* increased among relatives/friends across 11 (73%) of 15 health facilities ($P = 0.06$) (Table 6).

DISCUSSION

Results of this evaluation showed a sustained increase in knowledge and use of point-of-use water treatment products over baseline levels among antenatal program participants over a three-year period. This evaluation also demonstrated improved knowledge and sustained use of household water treatment with *WaterGuard* or chlorine stock solution among program participants' relatives and friends. An independent qualitative evaluation conducted in the same population after quantitative data collection in 2010 supports the hypothesis that the antenatal clinic intervention resulted in behavior change among participants and their relatives and friends.[9] Although loss to follow-up was high, the increase from baseline to follow-up in the above indicators remained statistically significant at the health facility level.

An analysis of the worst-case scenario in which none of the lost-to-follow-up participants would have had detectable chlorine residual continued using *WaterGuard* or chlorine stock solution, or reported *WaterGuard* purchase, indicated that increases after three years over baseline proportions for these indicators would have remained statistically significant at the clinic level. Therefore, we infer that the results of this evaluation demonstrate sustained improvements, in the presence of high loss to follow-up.

Improvements in water treatment behavior are not thought to have occurred throughout Malawi, as suggested by a 2010 household survey of water treatment practices in Machinga District that took place during the rainy season in a rural, cholera-affected region, and showed 0% confirmed use of *WaterGuard* (Loharikar A, unpublished data). Furthermore, national *WaterGuard* sales in Malawi decreased by 11% from 2009 through 2010. It is likely that the difference in rates of detectable chlorine residual compared with confirmed *WaterGuard* use and purchase in participant and relative/friends' homes reflects the use of free chlorine stock solution by respondents. We know of no other water treatment programs that occurred in project areas that could otherwise explain these findings. A qualitative evaluation conducted in the same population suggested that participants and their relatives and friends used a water treatment strategy that involved a combination of *WaterGuard* and stock chlorine solution that depended on the availability of each source of chlorine.[9] This qualitative evaluation also strongly suggested that the antenatal program was the principal factor motivating these water treatment behaviors.

There are several possible explanations for sustained successful promotion of water treatment behavior observed in this program. First, by integrating a household water treatment product and hygiene promotion with antenatal services, the

program targeted mothers during pregnancy; perhaps mothers are motivated by the impending birth of a newborn who requires maternal protection.[7,10] Second, community health workers continued to reinforce water treatment messages through repeated home visits as part of their programmed activities, and antenatal clinic staff delivered similar messages during antenatal visits, delivery, and postnatal check-up.[9] Previous research suggests that health workers are trusted sources of information that can help motivate their clients to change health behaviors.[11] Third, for many participants and relatives/friends who wanted to continue treating their water but did not want to purchase or could not afford *WaterGuard*, chlorine stock solution was made available at no charge by the Ministry of Health during the rainy season, effectively eliminating the economic barrier to water treatment. The main drawback to this free water treatment option is that it is available neither year-round nor in all locations, and lacks predictable temporal patterns of distribution. We lack data to help assess whether the government's program could be sustainable over the long term if chlorine stock solution were provided to the entire population year round.

In the Malawi evaluation, levels of confirmed chlorine use were substantially higher among program participants and relatives/friends at three years, perhaps because of the reasons listed above. Despite these encouraging results, substantial attrition in water treatment behaviors occurred during 2008–2010. A study from Guatemala noted even greater attrition in water treatment behavior after the transition from free distribution of a water treatment product in an efficacy study to a marketing program requiring purchase of the product.[12] In that study, a strictly commercial model was followed with no programmatic support from health workers. Among the barriers to use of the product, which consisted of a powder that flocculated and chlorinated stored water, were cost, inability to find the product, time required for water treatment, and taste. In the Malawi evaluation, the main reasons for discontinuing water treatment included cost, inability to find *WaterGuard*, and a belief that source water was clean or water treatment was not necessary. Another study in Cambodia noted similar attrition in the use of ceramic pot filters. Use of these filters, which were similar to containers commonly used in that population, decreased by a rate of approximately 2% per year.[13] The rate of use after approximately 3–4 years of observation was 31%.

This evaluation also observed attrition in use of the safe water storage vessel distributed at enrollment, from 91% in 2008[6] to 46% in 2010. Breakage of the vessel was the main reason for it no longer being used. This finding highlights the importance of having a programmatic provision for repairing or replacing safe water storage containers to maintain a desirable behavior, the removal of stored water through a tap, rather than by dipping, which increases the risk of recontamination of stored treated water. Household water storage in wide-mouthed, uncovered, containers, into which cups or other utensils are dipped to obtain water, has been repeatedly implicated in diarrheal disease transmission.[14–17]

Results of this evaluation also showed that the ability to demonstrate proper handwashing behavior was sustained over three years among program participants and their relatives/friends. These findings were consistent with at least two other studies that showed sustained handwashing knowledge after a relatively brief intervention.[18,19] Findings in this evaluation were not likely a result of other programs because local project team members did not report other interventions taking place in these villages. Furthermore, we observed that use of soap, ability to demonstrate correct handwashing technique, and presence of handwashing stations were substantially lower in villages in another survey in Machinga District, Malawi (Loharikar A, unpublished data). Although the handwashing assessment was based on observation, we did not have objective indicators of actual handwashing behavior, which is challenging and expensive to measure, and difficult to sustain over time.[20]

This evaluation had several limitations. First, because we used a convenience sample of 15 health facilities in 2 districts, the evaluation population was not necessarily representative of district-wide or national populations. In addition, little data were obtained from women from more remote communities because program enrollment and hygiene kit distribution did not take place in outreach clinics. Second, participation in the evaluation may have influenced program participants' behaviors and responses, which may not have been representative of all pregnant women who received the hygiene kit, or their friends and relatives. Third, the baseline evaluation was conducted in the dry season in 2007, and both follow-up evaluations were conducted in the rainy season. It is possible that during the rainy season more education on water treatment and free distribution of chlorine stock solution could have influenced water treatment practices. However, we examined Population Services International Malawi sales data and found that seasonal variations in *WaterGuard* sales were negligible compared with the changes in *WaterGuard* use observed in the evaluation population, suggesting that a factor other than social marketing, in this case, the antenatal integration program, may have influenced sustained purchase and use of the product. Fourth, because the free distribution of chlorine by the Ministry of Health is unique to Malawi, it is possible that sustained household water chlorination observed over the three-year period of this evaluation may not be easily replicable at the same level in other countries lacking such programs. Fifth, because of financial and logistical limitations, we were not able to measure health outcomes. Finally, this three-year follow-up evaluation had significant loss-to-follow-up from the 2007 baseline. We have attempted to account for the impact of this loss on outcomes in our analysis.

Results from this evaluation suggest that integrating public health interventions with antenatal services offers promising opportunities for motivating and sustaining behavior change. The finding that adoption of water treatment behavior was greater among rural, less educated, and poorer women in Salima District compared with Blantyre District in 2008[6] and 2010 demonstrates that this approach could help improve equity of access to this intervention, and perhaps other child survival interventions, in high-risk populations. Further expansion of this intervention is warranted, along with evaluations to carefully monitor impact on household practices and health.

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