

Evaluating the Efficacy of the Supertowel™ as a Handwashing Product: A Simulation of Real-World Use Conditions

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Abstract. The Supertowel is a fabric treated with a permanent antimicrobial bonding and has been designed as a soap alternative in emergency situations. The Supertowel has been shown to be as efficacious as handwashing with soap and water when tested under controlled laboratory conditions. It has also been shown to be a practical, acceptable, and desirable product among crisis-affected populations. The aim of this study was to test whether the Supertowel remains as efficacious when used under conditions which mimic real-world hand cleaning in challenging settings. Two rounds of laboratory tests, with 16 volunteers in each, were conducted to test the efficacy of the Supertowel when used for a shorter duration, when less wet, when used with contaminated water, when visibly dirty, and when dry. Volunteers pre-contaminated their hands with nonpathogenic *Escherichia coli*. Comparisons were made between hand cleaning with the Supertowel and the reference condition (normally handwashing with soap), using a crossover design. The Supertowel was marginally less efficacious than handwashing with soap when used for 15 seconds ($P = 0.04$) but as efficacious at 30 and 60 seconds durations. All the other Supertowel conditions were as efficient as their reference comparisons meaning that the Supertowel can effectively remove pathogens from hands when it is wet, damp, or completely dry, when it is used with contaminated water, when visibly dirty with mud and/or oil.

INTRODUCTION

Crisis-affected populations are at increased risk of diarrheal diseases^{1,2} and respiratory infections³ and outbreaks among displaced populations tend to be more severe.⁴ Water, sanitation and hygiene (WASH) interventions are key for interrupting disease transmission. Yet crises often cause damage to WASH infrastructure and humanitarian response sometimes struggles to meet these WASH-related needs rapidly and sufficiently. In particular, crisis-affected populations often lack access to sufficient handwashing facilities, soap, and water. Handwashing with soap has the potential to substantially reduce morbidity and mortality associated with diarrheal diseases^{5–9} and respiratory infections.^{10,11} Handwashing with soap also plays a key role in the prevention of outbreak related pathogens such as cholera,^{12–16} Ebola,¹⁷ and coronaviruses.¹⁸

Recognizing this situation, a range of innovators within the private sector, nongovernment organizations, and academia were tasked with developing products which could enable crisis-affected populations to more easily wash their hands.¹⁹ One of the innovations developed by Real Relief (www.realreliefway.com) as an alternative to soap was the Supertowel. The Supertowel is made from a microfiber cloth which is then treated with a permanent antimicrobial bonding. For hand cleaning, the Supertowel is dipped in water and then wiped over the hands thoroughly. The Supertowel can be washed and cleaned just like any other fabric, to remove visible dirt. The antimicrobial component does not involve the use of any toxic chemicals. It is achieved by long chains of carbon atoms attached to positively charged nitrogen atoms bonded to a silica layer of the fabric. The positively charged layer attracts negatively charged microbes (including bacteria, protozoa, fungi, and encapsulated viruses) causing membrane disruption of the microbes.

The antimicrobial technology has already been demonstrated to kill a range of pathogens²⁰ and in 2019 our team demonstrated that in controlled laboratory conditions the Supertowel was as effective as soap and water for removing pathogens from hands.²¹ Further laboratory studies showed that that after washing the product 100 times it was still highly efficacious.²² Therefore, it is assumed that the Supertowel could be used safely by crisis-affected populations for 6 months to a year. Further to this, we conducted a small-scale pilot study of the Supertowel in a refugee camp in northern Ethiopia to assess the acceptability and feasibility of the product.²³ Participants in the study reported that the Supertowel was an acceptable and useful hand-cleaning product that could complement soap use in crisis contexts. During the study, we were able to observe how people incorporated the Supertowel into their daily lives and found that it was particularly useful for handwashing when outside the home or when multiple hand washes are needed (such as the process of preparing food over several hours). The Supertowel is currently available to humanitarian agencies for USD 0.5 when ordered in large quantities.

The initial laboratory-based efficacy study had tested the Supertowel under ideal circumstances (based on EU standards)—use when wet and for 60 seconds. Building on our observations in Ethiopia, we realized it was necessary to explore the efficacy of the Supertowel under circumstances which more closely mirrored real-life use. For example, in community settings in high-income countries, handwashing with soap is typically done for 15 seconds or less,^{24–26} similarly in Ethiopia we noted that both handwashing with soap and Supertowel use was normally for much less than 60 seconds. This led us to our first research question: Is the Supertowel as efficacious as soap if used for hand cleaning for a short period of time? In Ethiopia, we also observed that people intuitively squeezed the Supertowel before use, and so our second research question aimed to understand whether the Supertowel is as efficacious as soap if used for hand cleaning when moist rather than soaking wet? In Ethiopia, we also observed that it was easy for the Supertowels to get

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visibly dirty with mud or oil and we wanted to know whether this might impair the efficacy of the product. Therefore, our third research question was: Is the Supertowel efficacious for hand cleaning if soiled and oily? We know that the water used for handwashing with soap does not have to be of potable quality.^{27,28} In many crisis-affected settings (like in our Ethiopia study), households have limited access to potable water but surface water and other unsafe water sources are more available. This shaped our last research question which was: If the Supertowel was soaked in contaminated water and then used for hand cleaning, would it be more efficacious than handwashing with soap and contaminated water?

This research focuses on answering each of these questions by simulating these of “real-world” hand cleaning conditions in the laboratory. This will be achieved by using an in vivo design with healthy volunteers in India and a protocol adapted from the European Committee for Standardization protocol (EN 1499).²⁹

METHODS

Two rounds of laboratory testing were conducted on the Supertowel. For the first round, we tested if the Supertowel was effective under four separate experimental conditions related to our initial research questions: 1) Is the Supertowel as efficacious as soap if used for hand cleaning for a short period of time? 2) Is the Supertowel as efficacious as soap if used for hand cleaning when moist rather than soaking wet? 3) Is the Supertowel efficacious for hand cleaning if soiled and oily? 4) If the Supertowel was soaked in contaminated water and then used for hand cleaning, would it be more efficacious than handwashing with soap and contaminated water?

We waited until the results of round one were obtained and then designed a new set of round two experiments which explored a combination of these different conditions. Two additional combination experiments were conducted during this round. Separate protocols were designed for each of the six experiments so that in each case the test condition could be compared with the most appropriate control condition (two procedures will be conducted for each experimental condition).

The studies were performed in the Department of Microbiology, Kelkar Education’s Trust’s (KET’s), Scientific Research Center, Mumbai (India). The first test took place in February 2020 and the second set of tests was conducted in March 2020. The studies were approved by the London School of Hygiene and Tropical Medicine Ethics Committee and the KET’s Institutional Scientific & Ethics Committee.

Microorganism. To test the efficacy of the Supertowel, we used an adapted protocol of the European Committee for Standardization (EN 1499)²⁹ which is designed to evaluate the ability of handwashing agents to eliminate transient pathogens from volunteer’s hands without regard to resident microorganisms. This procedure is based on the “post-contamination treatment” of hands and involves the placement of the test organism (*Escherichia coli* [ACTC 11229]) on the hands of test subjects followed by exposure of the test product.

Subjects. Sixteen adult male volunteers were selected for each of the laboratory test rounds. Informed written consent was obtained from all of them. The 32 volunteers were students at nearby universities and were recruited by using poster

advertisements which were placed within these nearby institutions. Eligible volunteers had to be older than 18 years, have short fingernails with no artificial nails, have no cuts or wounds on their hands, have no history of drug allergies, have healthy skin (people with skin disorders such as eczema, paronychia, psoriasis, scabies, abrasions, lacerations, or skin allergies were excluded) and must not have taken any antibiotics in the last 2 weeks. Participants were asked to remove rings from their hands before handwashing as jewelry can harbor bacteria.^{30,31} Indian regulations require that if any new product is to be tested on women, then they must undergo pregnancy screening. We did not want to subject female participants to this and, therefore, decided to include male participants only.

For each round of experiments, we used a crossover design. For round 1, each of the 16 volunteers tested the four experimental conditions and received eight different procedures (described in Table 1). We used a Latin Square design³² where 16 different sequences of the eight procedures were created beforehand. The sequences were allotted to individual volunteers by means of a number draw. This process meant that each volunteer used all of the handwashing procedures only once, and that this was carried out in the order prescribed by the randomly selected sequence. For round 2 (described in Table 1), we recruited 16 new volunteers who tried two new experimental conditions and received 3 handwashing procedures using the same strategy as in round 1. After each procedure, the volunteers were given medicated soap to wash their hands.

New product. The Supertowels used in all the tests were produced by Real Relief. The Supertowels used were made out of a microfiber terry towel fabric, composed of 80% Polyester and 20% Polyamide.

Contamination step. The hands of each volunteer were washed with a non-medicated soap and dried thoroughly with paper towels. Each volunteer spread their fingers apart and immersed them up to the mid-metacarpals for 5 seconds in a contamination fluid which contained nonpathogenic *Escherichia coli* (ACTC 11229) 8.3×10^8 cfu/mL. Hands were then air-dried for 3 minutes.

Pre-value. After drying, the fingertips of each volunteer’s left and right hands were rubbed on separate petri dishes containing 10 mL of TSB (without neutralizers) for 60 seconds. This was performed to establish a pre-value of the test organism before applying treatments or controls to the hands. Pre-values were calculated using the standard serial dilution method.³³

PROCEDURES: TREATMENTS AND CONTROL

First round of tests. Experiment 1. Treatment 1: Hand cleaning with the Supertowel for 15 seconds. The Supertowel was soaked in clean tap water by submersing it completely in a bucket filled with tap water. The amount of water absorbed by the Supertowel was recorded by means of weighing the towel before and after soaking. The volunteers used the soaked Supertowel for 15 seconds to clean their pre-contaminated hands.

Control 1: Handwashing with bar soap and water for 15 seconds. The control group washed their pre-contaminated hands with non-medicated bar soap (Pears® Bar Soap) and clean tap water for 15 seconds. Afterward, hands were air dried for 3 minutes.

TABLE 1
Description of treatments and controls from the different experiments conducted in rounds 1 and 2

Treatment	Round 1				Round 2			
	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Experiment 6	Experiment 6	
Supertowel	1T Supertowel soaked with clean water and used for 15 seconds	2T Supertowel soaked with clean water and then squeezed until damp and used for 60 seconds	3T Supertowel soaked with contaminated water and used for 60 seconds	4T Supertowel made visibly dirty with a mixture of soil, oil, and clean water and then used for 60 seconds	5T Supertowel made visibly dirty with a mixture of soil, oil, and contaminated water and used for 30 seconds	6T Supertowel completely dry and used for 60 seconds		
Control	1C Handwashing with non-medicated bar soap for 15 seconds	2C Handwashing with non-medicated bar soap for 60 seconds	3C Handwashing with non-medicated bar soap and contaminated water for 60 seconds	4C A clean Supertowel, soaked in clean water and used for 60 seconds	5C Handwashing with non-medicated bar soap and water for 30 seconds	6C Handwashing with non-medicated bar soap and contaminated water for 30 seconds		

Before doing both of the procedures aforementioned, a laboratory technician demonstrated to the volunteer how to use either the Supertowel or the bar soap for the required time. For example, for handwashing with soap, the volunteer was instructed to wet their hands for 3 seconds, lather the soap on their hands for the subsequent 5 seconds, and then rinse with water for the last 7 seconds. Thorough hand rubbing was encouraged throughout the three steps according to the illustrations provided in the WHO handwashing guidance.³⁴ The amount of water used for hand rinsing was collected from four volunteers. For the Supertowel, the volunteers were instructed to move the Supertowel over all surfaces of hands, including fingers, between the fingers, fingertips, and over the back of the hands (15 seconds in total). Adaptation of the hand cleaning demonstration steps was done for each of the soap and Supertowel experiments that are described in the following paragraphs.

Experiment 2. Treatment 2: Hand cleaning with a Supertowel that is damp for 60 seconds. The Supertowel was soaked in clean tap water by submersing it completely in a bucket filled with tap water. The water on the Supertowel was then squeezed out to the point where it was not dripping. The Supertowel was weighed before and after squeezing. Volunteers cleaned their pre-contaminated hands with the damp Supertowel for 60 seconds. Volunteers were instructed to move the Supertowel over all surfaces of hands, including fingers, between the fingers, fingertips, and over the back of the hands (60 seconds in total).

Control 2: Handwashing with bar soap and water for 60 seconds. The control group washed their pre-contaminated hands with non-medicated bar soap (Pears Bar Soap) and clean tap water for 60 seconds by following the WHO guidelines for handwashing guidelines.³⁴ After handwashing, hands were allowed to dry for 3 minutes. Volunteer were instructed to wet their hands for 3 seconds, lather the soap on their hands for the subsequent 42 seconds, and then rinse with water for the last 15 seconds. The amount of water used for hand rinsing was collected from four volunteers.

Experiment 3. Treatment 3: Hand cleaning for 60 seconds with a Supertowel that has been soaked in contaminated water. A Supertowel was soaked in water which was artificially

contaminated with nonpathogenic *E. coli*. The artificially contaminated water was designed to mimic highly contaminated gray water, so it was contaminated at 2,000 cfu/100 mL which is double the acceptable level of contamination for handwashing.²⁸ The level of contamination in water was controlled twice daily during the trial. Volunteers cleaned their pre-contaminated hands with the contaminated Supertowel for 60 seconds.

Control 3: Handwashing with non-medicated bar soap (Pears Bar Soap) and contaminated water for 60 seconds. The water was contaminated with nonpathogenic *E. coli*. at 2,000 cfu/100 mL and was stored in a bucket which had a tap at the base. The control group volunteers washed their hands with the contaminated water and non-medicated bar soap for 60 seconds. A diagram of the WHO steps for handwashing was given to them.³⁴ After handwashing, hands were allowed to dry for 3 minutes. The amount of water used for hand rinsing was collected from four volunteers.

Before doing both of the procedures aforementioned, a laboratory technician demonstrated to the volunteer how to use either the Supertowel or the bar soap for the required time (same times and steps were used as in experiment 2).

Experiment 4. Treatment 4: Hand cleaning for 60 seconds with a Supertowel that is visibly dirty and oily.

The Supertowel was made visibly dirty and oily by immersing it in a mix of 5 g of sterile soil (previously autoclaved), 5 mL of clean cooking oil and 100 mL of clean tap water. The Supertowel was rubbed against itself to ensure the water, soil, and oil were spread out across the surface of the Supertowel. No additional water was added to the Supertowel. Volunteers cleaned their pre-contaminated hands with the dirty Supertowel for 60 seconds.

Control 4: Hand cleaning for 60 seconds with a clean Supertowel. The Supertowel was soaked in clean tap water by submersing it completely in a bucket filled with clean tap water. The amount of water absorbed by the Supertowel was recorded by means of weighing the Supertowel before and after soaking. The control group cleaned their pre-contaminated hands of with the soaked Supertowel for 60 seconds.

In both procedures, volunteers were instructed to move the Supertowel over all surfaces of hands, including fingers,



FIGURE 1. Pictures of the Supertowel being used as part of the laboratory experiments. This figure appears in color at www.ajtmh.org.

between the fingers, fingertips, and over the back of the hands (60 seconds in total).

Second round of tests. Experiment 5. Treatment 5: Hand cleaning for 30 seconds with a Supertowel that is visibly dirty and oily and is soaked in artificially contaminated water. The Supertowel will be made visibly dirty and oily by immersing it in a mix of 5 g of sterile soil (previously autoclaved), 5 mL of clean cooking oil, and 100 mL of contaminated water. Water was contaminated using the same process as described in experiment 3. The Supertowel will be rubbed against itself to ensure the water, soil, and oil are spread out across the surface of the Supertowel. No additional water was added to the Supertowel. Volunteers cleaned their pre-contaminated hands with the dirty Supertowel for 30 seconds.

Control 5: Handwashing with bar soap and contaminated water for 30 seconds. As per experiment 3, water was contaminated with nonpathogenic *E. coli* at 2,000 cfu/100 mL and stored in a bucket which had a tap at the base. The control group volunteers washed their hands with the contaminated water and non-medicated bar soap for 30 seconds. A diagram of the WHO steps for handwashing was given to them to guide the hand cleaning process.³⁴ After handwashing, hands were allowed to dry for 3 minutes.

Experiment 6. Treatment 6: Hand cleaning for 60 seconds with a completely dry Supertowel. Volunteers cleaned their pre-contaminated hands with the dry Supertowel for 60 seconds.

Control 6: Same as the control for experiment 5.

Post-values. Post-values were collected in the same manner as the pre-values. When the hands were fully dry, the volunteers rubbed the fingertips of the left, and right hands were rubbed in separate petri dishes containing 10 mL of TSB (without neutralizers) for 60 seconds, to assess the release of test organism after treatment of the hands. After completing all procedures, the volunteers were given antimicrobial soap to wash their hands.

Quality assurance. Three of the authors were present in the first round of experiments, and one of the authors (R. K.) was present for all of the tests to maintain standardization and monitor quality. A subsample of participants were video-recorded while completing the tests to verify that each step of the process was followed accurately.

Statistical analysis. For both the Supertowel and control procedures, log counts of *E. coli* from the left and right hands of each subject were averaged separately, for both pre- and post-values. The arithmetic means of all individual \log_{10} reduction values were calculated. The analysis was performed using STATA version 16.0. The distribution of the data was assessed using Kurtosis and Skewness tests. Given that the data were not normally distributed, nonparametric tests were used. We used a Kruskal–Wallis test to assess whether a

statistically significant difference on the \log_{10} reduction effect of two or more procedures was observed in each round. If evidence of a statistical significant difference was observed, we then used a post hoc pair-wise test (Wilcoxon signed rank tests) to assess the differences between specific pairs. The new Supertowel condition was considered to have the same efficacy as its reference condition if the mean \log_{10} reduction factor was not significantly smaller for the former than for the latter. We also apply the same criteria to compare effects on \log_{10} reduction of *E. coli* between different treatments or control procedures tested among the same volunteers. Wilcoxon rank sum (Mann–Whitney) test were used to test the differences in effects on \log_{10} reduction of *E. coli* between procedures from different volunteers (treatments or controls from volunteers from round 1 with treatments or controls from volunteers from round 2). Because of the confirmative nature of the test on this application, the level of significance is set at $P < 0.05$, and the test used is one-sided. The discrimination efficiency of the test procedure described has been set to detect a difference between the two mean log reduction factors of approximately 0.6 log at a power of 95%, and the SD of the distributions of log reductions used in both groups was 0.28. This results in a sample size of $N = 16$ for each set of experiments.

RESULTS

All participants were male, lived in an urban area of Mumbai, and ranged in age from 18 to 43 years (average age 25).

Table 2 describes the results from all the experiments for rounds 1 and 2. The overall mean of the log pre-values was 7.1 and the maximum detectable log reduction observed in all the procedures from all the volunteers was 4.62 (see Supplemental Data). Figure 2 shows the results of the first round of experiments. We observed differences in log reduction with the different procedures (Kruskal–Wallis P -value = 0.0001). We found that in Experiment 1, the reduction observed when volunteers cleaned their hands with the wet Supertowel for 15 seconds was 2.71 ± 0.35 , which was marginally less effective than the reference hand wash with soap for 15 seconds, 2.96 ± 0.54 ($P = 0.04$). All the other Supertowel treatment conditions were as efficient as their reference comparisons. The damp Supertowel (treatment 2) was as efficient as handwashing with soap when done for 60 seconds ($P = 0.58$). When the Supertowel was soaked with artificially contaminated water and used for 60 seconds (treatment 3), its efficacy was not statistically different as handwashing with soap and rinsing with contaminated water ($P = 0.12$). The Supertowel also demonstrated the same efficacy in mean \log_{10} -reductions, when it was artificially made dirty with soil and oil and used for 60 seconds (treatment 4) compared with a clean version of the Supertowel used for the same duration ($P = 0.34$). Handwashing with soap for 15 seconds was less efficient than all the other procedures which used 60 seconds for handwashing (with exception of using the Supertowel soaked in contaminated water, which had the same efficacy). Using the Supertowel when soaking wet for 60 seconds was as efficacious as when it was damp (after being squeezed to remove water) and used for the same duration ($P = 0.71$). The Supertowel soaked in artificially contaminated water and used for 60 seconds was less efficient than using the Supertowel which had been made visibly dirty ($P = 0.006$).

TABLE 2

Mean log reduction factor of *Escherichia coli* after volunteers cleaned their hands with either the Supertowel (treatment) or control procedures

Product	Mean log ₁₀ reduction factor Supertowel (SD)	Mean log ₁₀ reduction factor control (SD)	Difference	P-value
Phase 1 tests:				
Treatment 1 (reduced hand cleaning duration)	2.71 (0.35)	2.96 (0.54)	0.25	0.04
Treatment 2 (reduced wetness of the Supertowel)	3.27 (0.51)	3.39 (0.55)	0.12	0.58
Treatment 3 (hand cleaning with contaminated water)	3.13 (0.47)	3.29 (0.40)	0.16	0.12
Treatment 4 (dirty Supertowel)	3.52 (0.37)	3.33 (0.56)	0.19	0.34
Phase 2 test:				
Treatment 5 (dirty Supertowel, contaminated water and use for 30 seconds)	3.50 (0.44)	3.33 (0.34)	0.18	0.4
Treatment 6 (dry Supertowel)	3.62 (0.46)	3.33 (0.34)	0.31	0.02

P-values were derived using Wilcoxon's matched pair signed-rank tests.

The process of handwashing for 15 seconds with the reference soap and under water flowing from a tap consumed (760 ± 37) mL of water (water collected during the last 7 seconds when hands were rinsed). Handwashing for 60 seconds with the same soap and under the same tap consumed $1,650 \pm 45$ mL water (water collected during the last 15 seconds when hands were rinsed). When hands were washed for 60 seconds with reference soap and contaminated water dispensed from a bucket with a tap, an average of 865 ± 48 mL of water was consumed. The Supertowel absorbed on average (143.8 ± 11.3) mL when soaked in water and 52.4 ± 23.1 mL when squeezed manually.

After the first round of findings, the trial committee met and discussed the experiment results to plan for the second round of tests. It was decided that we should test the efficacy of the Supertowel when used for 30 seconds, as in the previous experiments we observed that the efficacy of using the Supertowel for 15 seconds was lower than all the other conditions. In the same treatment, we decided to also apply the "worst" of the other conditions as our round one experiments demonstrated that the Supertowel performed relatively well when visually dirty and when soaked in contaminated water. Second, because our initial experiments showed that the

Supertowel was as efficient when damp, we decided to check the efficacy of the Supertowel when used completely dry (without adding any water). The results from the second round of experiments are in Table 2 and Figure 3. The Supertowel used for 30 seconds, when visibly dirty and with contaminated water (treatment 5) was as efficient as handwashing with soap and contaminated water for 30 seconds ($P = 0.4$). The Supertowel used for 60 seconds when totally dry (treatment 6) was more efficient than handwashing with soap for 30 seconds and rinsed with contaminated water ($P = 0.02$).

We compared experiments from round 1 and round 2, to compare the various conditions used with the Supertowel. We observed that Supertowel used for 30 seconds, dirty and wet in contaminated water, was more efficient than handwashing with water for 15 seconds ($P = 0.01$) and as efficient as handwashing with soap for 60 seconds ($P = 0.77$). When the Supertowel was visibly dirty, dipped into contaminated water, and used for 30 seconds (treatment 5), it was more efficient than using the clean Supertowel with clean water for 15 seconds ($P = 0.001$). The Supertowel condition in treatment 5 was also as efficient as using the Supertowel for 60 seconds when soaking wet in clean water or in contaminated water or used when dirty and oily ($P = 0.68, P = 0.06, P = 0.72$, respectively). A

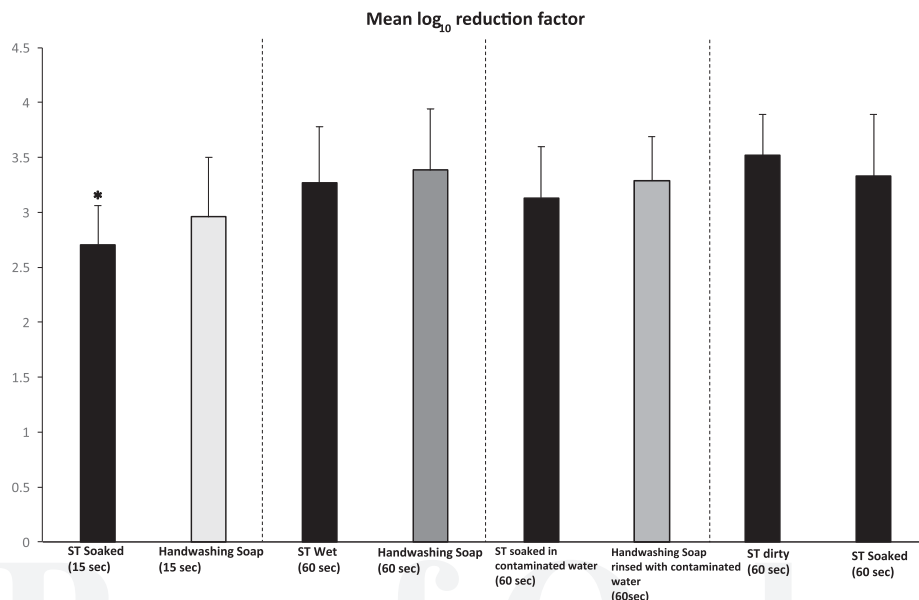


FIGURE 2. Round 1 experiment results showing the mean log reduction factor of *Escherichia coli* after volunteers washed their hands with either the Supertowel under different treatments or control procedures.

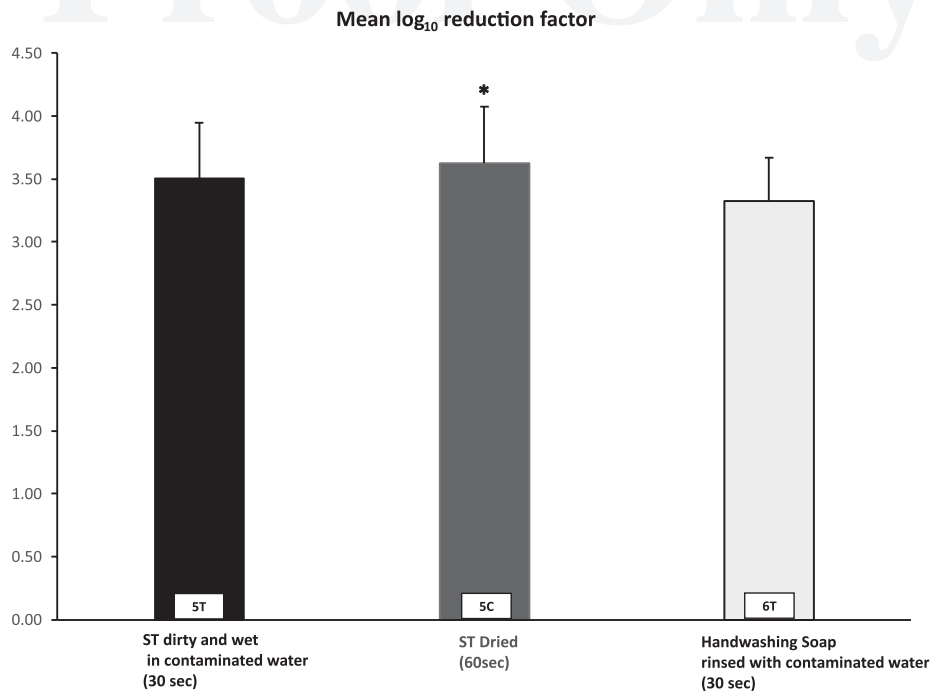


FIGURE 3. Round 2 Experiment results showing the mean log reduction factor of *Escherichia coli* after volunteers washed their hands with either the Supertowel under different treatments or control procedures.

dry Supertowel used for 60 seconds (treatment 6) was found to be equally efficacious as a Supertowel that is soaked or wet during 60 seconds ($P = 0.18$ and $P = 0.06$, respectively). Handwashing with soap for 15 seconds was less efficient than handwashing with contaminated water for 30 seconds ($P = 0.031$) and handwashing during 60 seconds ($P = 0.029$). However, handwashing with soap for 30 seconds with contaminated water was as efficient as handwashing with soap with clean water for 60 seconds ($P = 0.74$).

DISCUSSION

Our study aimed to develop practical recommendations for the use of the Supertowel in crisis-affected settings, and therefore, each of our experiments were designed to simulate the real-world realities of hand cleaning in emergencies. The Supertowel was as effective as the control conditions at removing bacteria from hands under five of the six experiments which we performed. The exception to this was in the first procedure where we found that cleaning hands for 15 seconds with a wet Supertowel is marginally less efficient than handwashing with soap and water for the same duration ($P = 0.04$).

Our results from experiment 1 and 5 indicate that populations should be instructed to use the Supertowel for 30 seconds to get hands optimally clean. These recommendations are consistent with current guidelines for handwashing with soap. Despite the reduced efficacy of the Supertowel at 15 seconds, there are likely to be clear benefits of using the Supertowel for shorter durations as the bacteria reduction at 15 seconds was still relatively high. Certainly shorter durations would be much more efficacious than not cleaning hands.

The results from experiments 3 and 5 indicate that the Supertowel can be used with unclean water such as gray water or surface water from rivers and lakes as the Supertowel

appears to be able to remove and kill pathogens on hands and within contaminated water. The results from experiments 4 and 5 indicate that even when the Supertowel becomes visibly soiled or oily it is likely to maintain its efficacy for hand cleaning. Although most populations are likely to want to regularly launder the Supertowel when it becomes visibly dirty, these findings do still provide greater flexibility with regard to the product use.

Despite microfiber cloths generally working better when wet,³⁵ our results from experiments 2 and 6 indicate that the Supertowel appears to remove pathogens from hands effectively when damp or dry. The ability to use the Supertowel while damp affords crisis-affected populations the opportunity to use the product in a more diverse set of circumstances and to minimize water use. The results of the efficacy of the Supertowel when used completely dry are promising; however, at this stage, we would recommend further testing before this it is taken up as a recommendation. There are three reasons for this. First, in our study, the dry towel was used for 60 seconds and compared with handwashing with soap for 30 seconds which may not be a fair comparison given the different time durations. Second, the Supertowel may be slightly less desirable to use on hands when dry because it will feel more rough, thus some further piloting should be conducted. Third, this experiment demonstrated that water is not essential for the Supertowel to remove pathogens from hands; however, water may also play an important role in enabling the antimicrobial treatment to kill pathogens, as it acts as a media. Therefore, we propose to do further pathogen “kill tests” with the dry Supertowel.

Our study also contributes to broader understandings about the efficacy and practicalities of handwashing with soap. Specifically, experiment 3 demonstrated that handwashing with soap and contaminated water is still effective in

removing pathogens, consistent with other studies.^{27,28} Our finding from experiments 1, 2, and 5 are consistent with broader evidence,³⁶ which suggests that hands should be washed for more than 15 seconds but that there may be diminishing returns for handwashing durations longer than 30 seconds. Results from these same procedures do indicate that handwashing with soap can be quite water intensive (using an average of 760 mL for 15 seconds and 1,650 mL for 60 seconds of handwashing with soap). Bucket-style handwashing facilities, as used in experiment 3, did seem to contribute to water savings. Our findings are similar to other studies which explored handwashing water consumption from piped taps or buckets with taps.³⁷ Across all experiments, the Supertowel was found to be substantially more water saving.

Limitations. Our research used an adapted version of the European Committee Standard for evaluating hands anti-septic agents. These standards are designed to assess the efficacy of cleaning products which are to be used in health-care settings. Currently, there is no equivalent laboratory standard for assessing hand cleaning products that are likely to be used in household or community settings as is the case for the Supertowel. As such we have no meaningful way of gaging what size of bacterial log reduction could have a meaningful public health impact within domestic settings.^{38,39} However, we used the same protocol in our previous Supertowel laboratory study,²¹ and it has also been used to test the efficacy of *Moringa Oleifera* plant powder for hand cleaning.⁴⁰

Our study explored the efficacy of the Supertowel at removing *E. coli* from the hands of volunteers. This form of nonpathogenic *E. coli* provided a safe way to explore these research questions with human subjects. However, it is possible that there will be variability in the mechanical ability of the Supertowel microfiber to remove other pathogens from hands. This pathogen-specific variability in removal rates is seen for handwashing with soap as well.³⁶ To assess this further, we plan to do other laboratory tests on the efficacy of the Supertowel against other microorganisms. We are also planning to do efficacy testing on Supertowels that are currently being used in a displacement camp in northern Nigeria. This will aim to assess whether the controlled laboratory test conditions mirror efficacy after long-term use in a humanitarian context.

CONCLUSION

This study contributes to a small but growing body of literature on the Supertowel as an alternative to soap for crisis-affected settings. Our results from experiments 1 and 5 indicate that populations should be instructed to use the Supertowel for 30 seconds to get hands optimally clean. These recommendations are consistent with current guidelines for handwashing with soap. Despite the reduced efficacy of the Supertowel at 15 seconds, there are likely to be clear benefits of using the Supertowel for shorter durations as the bacteria reduction at 15 seconds was still relatively high. Certainly shorter durations would be much more efficacious than not cleaning hands.

The results will allow for practical recommendations to be made in relation to the Supertowel's optimal use in these settings and will also help to inform further research on this product. The Supertowel is likely to be a viable alternative to

soap in settings where water is limited or contaminated and where handwashing is challenging to prioritize.

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ID	Reduction Factor Round 1				
	used for 15se	HW15sec-1C	ST60secSquez-2	HW60sec-2C	STContam-3T
1	2.46	4.03	2.30	4.41	3.50
2	2.64	3.48	3.90	4.06	3.71
3	3.16	3.37	4.02	3.43	3.28
4	2.89	3.11	3.66	3.50	3.01
5	2.25	2.07	2.74	2.96	2.60
6	3.17	3.01	3.09	3.20	3.49
7	2.93	2.61	3.53	3.56	3.86
8	2.68	3.12	4.08	3.76	3.51
9	1.96	2.46	2.99	3.08	2.60
10	2.47	2.41	2.83	3.02	3.21
11	2.34	2.07	2.79	1.96	2.80
12	2.88	3.32	3.22	3.44	2.51
13	3.20	3.39	3.73	3.64	3.06
14	2.61	2.81	3.26	2.89	2.28
15	2.72	3.24	3.22	3.72	3.14
16	2.95	2.87	2.91	3.53	3.53
Average	2.71	2.96	3.27	3.39	3.13
Std. dev	0.35	0.54	0.51	0.55	0.47

			Reduction factor Round 2	
HWContamW-3C	Stdirty-4T	ST60secSoak-4C	Stdirty&cont	STDried
3.66	3.99	3.65	3.20	3.71
4.08	3.76	3.57	3.91	3.49
3.82	4.19	3.11	4.08	4.24
3.19	3.72	3.87	3.38	2.96
2.78	3.03	3.22	3.29	3.81
2.85	3.23	2.64	4.61	4.62
2.91	3.49	4.11	3.09	3.28
3.51	3.47	3.70	3.95	3.78
3.23	3.22	3.14	3.19	3.45
3.01	3.18	3.31	3.39	3.82
2.84	3.34	2.00	2.80	3.43
3.43	3.64	3.77	3.76	3.94
3.63	3.94	3.33	3.64	4.10
2.85	2.82	2.52	3.17	2.86
3.26	3.50	3.40	3.38	3.18
3.54	3.74	3.93	3.24	3.33
3.29	3.52	3.33	3.50	3.62
0.40	0.37	0.56	0.44	0.46

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HWContamw-30sec

3.70

3.86

3.25

2.41

3.54

3.61

3.28

3.13

3.29

3.44

3.06

3.60

3.22

3.19

3.69

3.01

3.33

0.34
