

**Report for PhoneSoap on effectiveness of UV-C light on
Killing vegetative cells of *Staphylococcus aureus* ATCC
2593, *Staphylococcus aureus* MRSA, *Salmonella enterica*
subsp. *enterica* serovar Typhimurium ATCC 14028, and
Escherichia coli ATCC 8739.**

Prepared for

PhoneSoap

By

BLACKROCK CONSULTING AND SERVICES

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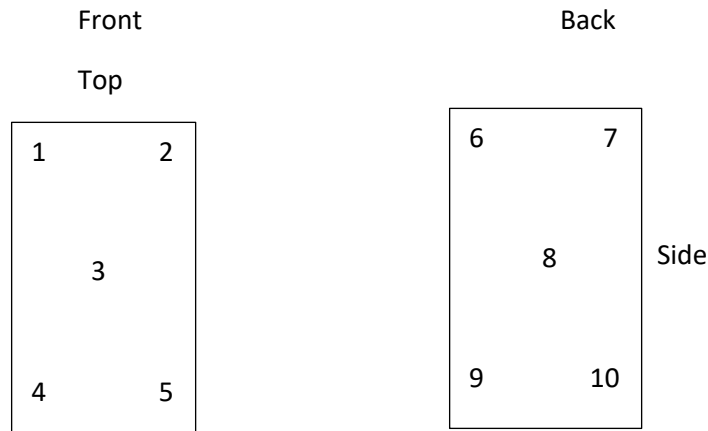
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Report for PhoneSoap on effectiveness of UV light on Killing vegetative cells of *Staphylococcus aureus* ATCC 2593, *Staphylococcus aureus* MRSA, *Salmonella enterica* subsp. *enterica* serovar Typhimurium ATCC 14028, and *Escherichia coli* ATCC 8739.

Methods and Materials:

Preparation of cultures. Suspensions of twenty-four-hour cultures of *Staphylococcus aureus* ATCC 25923 (*Staph. aureus*), a methicillin resistant strain of *Staphylococcus aureus* (MRSA), *Salmonella enterica* subsp. *enterica* serovar Typhimurium ATCC 14028 (*Sal. enterica*) and *Escherichia coli* ATCC 8739 (*E. coli*) were prepared in five percent sterile fetal bovine serum with a colony forming units (CFU) between 10^5 and 10^8 CFU per 0.02 ml and applied to iPhones and iPads as shown below. A second series of tests were performed on watches, baby bottles, glasses, headphones, tweezers, a TV remote and a game controller.



Exposure to UV light: After the applied spots dried, one set of iPhones and iPads and addition items was placed in PhoneSoap’s HomeSoap UV-C device and exposed to UV light for 10 minutes. A separate set of iPhones and iPads and additional items was exposed to UV light for 15 minutes. The iPhones and iPads were placed in a vertical position in the HomeSoap device. The watches, baby bottles, glasses, headphones, tweezers, TV remote and game controller were placed flat on the bottom of the HomeSoap Device with the spots where the bacteria had been applied facing up toward the top of the device.

External UV light emitted: A Sper Scientific UVC light meter model 850010 was used to determine if spurious UV-C light was being emitted from the HomeSoap device. The meter was moved around all the edges near openings.

Ozone emissions: Ozone levels were measured inside the HomeSoap device during a ten-minute cycle using an Aeroqual Series 200 ozone meter.

Incubation of agar plates: After exposure to UV light, each dried spot was wiped with a damp sterile cotton swab which was then used to inoculate a blood agar plate (BAP). The BAPs were then incubated at 30°C for 24 hours and CFUs counted.

Results:

Table 1 iPhone				
Microbe	<i>Staph aureus</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	>99.99998%	>6.67	99.99768%	4.63
2	99.99996%	6.37	99.99813%	4.73
3	99.99981%	5.72	99.99834%	4.78
4	99.99953%	5.33	>99.99998%	>6.67
5	99.99989%	5.97	99.99996%	6.37
6	99.99987%	5.89	99.99998%	6.67
7	99.99745%	4.59	>99.99998%	>6.67
8	99.99904%	5.02	99.99940%	5.22
9	99.99989%	5.97	>99.99998%	>6.67
10	99.99987%	5.89	99.99843%	4.80
Top	99.99738%	4.58	99.99766%	4.63
Side	99.99981%	5.72	99.99991%	6.07

Table 2 iPad				
Microbe	<i>Staph aureus</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	99.98936%	3.97	99.99968%	5.50
2	99.98936%	3.97	99.99981%	5.72
3	99.99617%	4.42	99.99930%	5.15
4	99.99149%	4.07	>99.99998%	>6.67
5	99.98511%	3.83	99.99996%	6.37
6	99.98723%	3.89	99.99998%	6.67
7	99.99911%	5.05	>99.99998%	>6.67
8	99.99940%	5.22	99.99940%	5.22
9	99.99894%	4.97	>99.99998%	>6.67
10	99.99911%	5.05	99.99843%	4.80
Top	99.99996%	6.37	99.99766%	4.63
Side	99.99862%	4.86	99.99991%	6.07

Table 3 iPhone				
Microbe	MRSA			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	99.99758%	4.62	>99.99998%	>6.92
2	99.99984%	5.80	>99.99998%	>6.92
3	>99.99998%	>6.92	99.99999%	6.92
4	>99.99998%	>6.92	>99.99998%	>6.92
5	99.99758%	4.62	>99.99998%	>6.92
6	99.99999%	6.92	99.99999%	6.92
7	99.99996%	6.44	99.99990%	6.01
8	>99.99998%	>6.92	99.99976%	5.62
9	>99.99998%	>6.92	99.99758%	4.62
10	>99.99998%	>6.92	>99.99998%	>6.92
Top	99.99961%	5.41	>99.99998%	>6.92
Side	99.99962%	5.43	>99.99998%	>6.92

Table 4 iPad				
Microbe	MRSA			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	99.99991%	6.31	99.99999%	6.92
2	99.99968%	5.74	>99.99998	>6.92
3	99.99979%	5.92	99.99925%	5.12
4	99.99994%	6.44	>99.99998	>6.92
5	99.99991%	6.31	99.99697%	4.52
6	99.99921%	5.35	99.99998%	6.62
7	99.99574%	4.62	99.99937%	5.20
8	99.99917%	5.33	99.99824%	4.76
9	99.99889%	5.20	99.99953%	5.33
10	99.99681%	4.74	99.99902%	5.01
Top	99.99521%	4.56	99.99867%	4.88
Side	99.99996%	6.62	99.99998%	6.62

Table 5 iPhone				
Microbe	<i>Sal. enterica</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	99.99926%	5.13	99.99980%	5.70
2	99.99968%	5.49	99.99991%	6.04
3	99.99955%	5.35	99.99989%	5.97
4	>99.99998%	>6.74	>99.99998%	>6.74
5	>99.99998%	>6.74	>99.99998%	>6.74
6	99.99549%	4.35	99.99966%	5.47
7	99.99870%	4.89	99.99986%	5.84
8	99.99603%	4.40	99.99886%	4.94
9	99.99603%	4.40	99.99870%	4.89
10	99.99639%	4.44	99.99993%	6.14
Top	99.99996%	6.44	99.99991%	6.04
Side	99.99968%	5.49	99.99993%	6.14

Table 6 iPad				
Microbe	<i>Sal. enterica</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	99.99423%	4.24	99.99912%	5.05
2	99.99748%	4.60	>99.99998%	>6.74
3	99.99933%	5.18	99.99986%	5.84
4	99.99531%	4.33	99.99931%	5.16
5	99.99459%	4.27	99.99948%	5.28
6	99.94590%	3.27	99.99784%	4.66
7	99.94590%	3.27	99.99098%	4.04
8	99.99847%	4.81	99.99279%	4.14
9	99.94590%	3.27	99.99098%	4.04
10	99.94590%	3.27	99.99459%	4.27
Top	99.99960%	5.40	99.99993%	6.14
Side	>99.99998%	>6.74	>99.99998%	>6.74

Table 7 iPhone				
Microbe	<i>E. coli</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	>99.99998%	>6.78	>99.99998%	>6.78
2	>99.99998%	>6.78	>99.99998%	>6.78
3	>99.99998%	>6.78	>99.99998%	>6.78
4	>99.99998%	>6.78	>99.99998%	>6.78
5	>99.99998%	>6.78	>99.99998%	>6.78
6	>99.99998%	>6.78	>99.99998%	>6.78
7	99.99978%	5.66	>99.99998%	>6.78
8	>99.99998%	>6.78	>99.99998%	>6.78
9	>99.99998%	>6.78	>99.99998%	>6.78
10	>99.99998%	>6.78	>99.99998%	>6.78
Top	>99.99998%	>6.78	>99.99998%	>6.78
Side	>99.99998%	>6.78	>99.99998%	>6.78

Table 8 iPad				
Microbe	<i>E. coli</i>			
Spot	10 minutes		15 minutes	
	% Killed	Log Reduction	% Killed	Log Reduction
1	>99.99998%	>6.78	>99.99998%	>6.78
2	>99.99998%	>6.78	>99.99998%	6.48
3	>99.99998%	>6.78	>99.99998%	>6.78
4	>99.99998%	>6.78	>99.99998%	>6.78
5	>99.99998%	>6.78	>99.99998%	>6.78
6	>99.99998%	>6.78	99.99982%	6.48
7	99.99982%	5.66	99.99967%	>6.78
8	99.99967%	>6.78	>99.99998%	>6.78
9	>99.99998%	>6.78	>99.99998%	6.48
10	>99.99998%	>6.78	99.99817%	6.78
Top	>99.99998%	>6.78	>99.99998%	5.82
Side	>99.99998%	>6.78	99.99997%	6.48

Table 9						
Watch	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
<i>Staph. aureus</i>	112	99.99925%	5.13	500	99.99667%	4.48
<i>MRSA</i>	0	>99.99985%	>5.82	0	>99.99985%	>5.82
<i>Sal. enterica</i>	17	99.99595%	4.39	3	99.99929%	5.15
<i>E. coli</i>	7	99.99998%	6.67	16	99.99995%	6.31

Table 10						
Baby Bottle	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
<i>Staph. aureus</i>	1	99.99999%	7.18	0	>99.99999%	>7.18
<i>MRSA</i>	0	>99.99985%	>5.82	0	99.99999%	>5.82
<i>Sal. enterica</i>	63	99.98500%	3.82	0	>99.99985%	>5.82
<i>E. coli</i>	0	>99.99999%	>7.18	63	99.98500%	5.72

Table 11						
Glasses	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
<i>Staph. aureus</i>	280	99.99813%	4.73	10	99.99993%	6.18
<i>MRSA</i>	300	99.99909%	5.04	200	99.99939%	5.22
<i>Sal. enterica</i>	165	99.96071%	3.41	95.00	99.97738%	3.65
<i>E. coli</i>	280	99.99915%	5.07	89	99.99973%	5.57

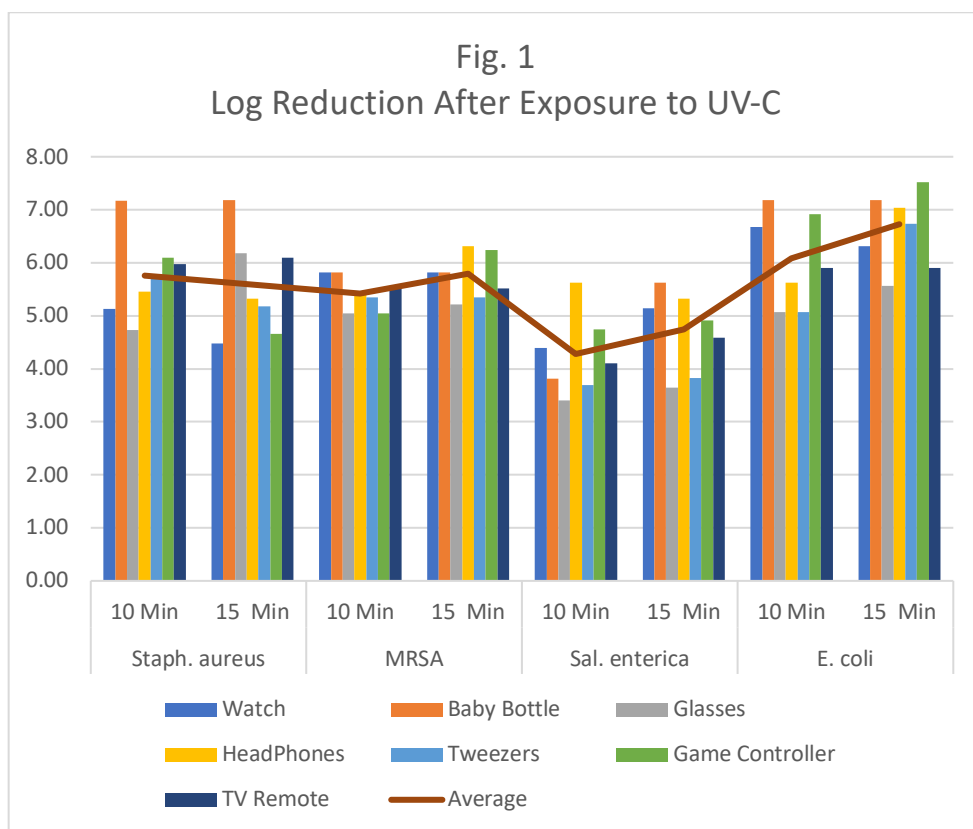
Table 12						
Headphones	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
<i>Staph. aureus</i>	3	99.99998%	6.70	8	99.99995%	6.27
<i>MRSA</i>	114	99.99965%	5.46	16	99.99995%	6.31
<i>Sal. enterica</i>	0	>99.9980%	>5.62	2	99.99952%	5.32
<i>E. coli</i>	0	>99.9998%	>5.62	3	99.99999%	7.04

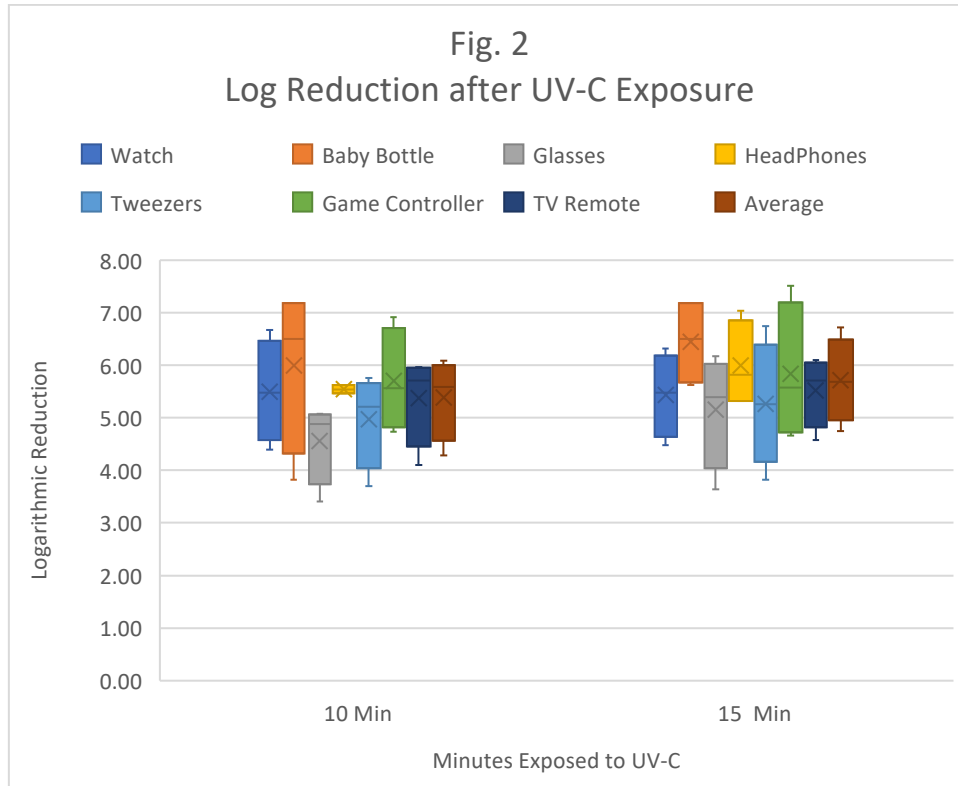
Table 13						
	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
Tweezers						
<i>Staph. aureus</i>	26	99.99983%	5.76	100	99.99933%	5.18
<i>MRSA</i>	150	99.99955%	5.34	150	99.99955%	5.34
<i>Sal. enterica</i>	84	99.98000%	3.70	63	99.98500%	3.82
<i>E. coli</i>	280	99.99915%	5.07	6	99.99998%	6.74

Table 14						
	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
Game Controller						
<i>Staph. aureus</i>	12	99.99992%	6.10	325	99.99783%	4.66
<i>MRSA</i>	300	99.99909%	5.04	19	99.99994%	6.24
<i>Sal. enterica</i>	600	99.99818%	4.74	400	99.99879%	4.92
<i>E. coli</i>	4	99.99999%	6.92	1	99.999997%	7.52

Table 15						
	10 Minutes UV-C Exposure			15 Minutes UV-C Exposure		
	CFU	% kill	Log	CFU	% kill	Log
			Red			Red
TV Remote						
<i>Staph. aureus</i>	16	99.99989%	5.97	12	99.99992%	6.10
<i>MRSA</i>	2	99.9997%	5.52	2	99.9997%	5.52
<i>Sal. enterica</i>	33	99.99214%	4.10	11	99.99738%	4.58
<i>E. coli</i>	0	>99.99988%	>5.90	0	>99.99988%	>5.90

Table 16									
Summary of Log Reduction After Exposure to UV-C light									
ITEM	<i>Staph. aureus</i>		MRSA		Sal. enterica		E. coli		
	10 Min	15 Min	10 Min	15 Min	10 Min	15 Min	10 Min	15 Min	
Watch	5.13	4.48	5.82	5.82	4.39	5.15	6.67	6.31	
Baby Bottle	7.18	7.18	5.82	5.82	3.82	5.62	7.18	7.18	
Glasses	4.73	6.18	5.04	5.22	3.41	3.65	5.07	5.57	
Headphones	5.46	5.32	5.46	6.31	5.62	5.32	5.62	7.04	
Tweezers	5.76	5.18	5.34	5.34	3.70	3.82	5.07	6.74	
Game Controller	6.10	4.66	5.04	6.24	4.74	4.92	6.92	7.52	
TV Remote	5.97	6.10	5.52	5.52	4.10	4.58	5.90	5.90	
Average	5.76	5.58	5.42	5.79	4.28	4.75	6.09	6.73	





Discussion and Summary:

The percent killed was determined by the following equation: $\frac{((\text{Number of bacteria applied to spot}) - (\text{Number of bacteria on spot after UV-C exposure}))}{\text{Number of bacteria applied to spot}} \times 100$.

$$\text{Percent Reduction} = \frac{(A - B) \times 100}{A}$$

Where:

A is the number of viable microorganisms before treatment,

B is the number of viable microorganisms after treatment

Logarithmic reduction was determined by the following equation: $\text{Log}_{10}(\text{Number of bacteria applied to spot}/\text{Number of bacteria on spot after UV-C exposure})$.

$$\text{Log Reduction} = \log_{10}\left(\frac{A}{B}\right)$$

or,

$$\text{Log Reduction} = \log_{10}(A) - \log_{10}(B)$$

Where:

A is the number of viable microorganisms before treatment,

B is the number of viable microorganisms after treatment

The average logarithmic reduction of *Staph. aureus* on iPhones for 10- and 15-minutes was 5.64 and 5.66 respectively. The average logarithmic reduction of *Staph. aureus* on iPads for 10- and 15-minutes was 4.64 and 5.85 respectively. For the MRSA strain of *Staph. aureus* at 10- and 15-minutes on iPhones, the average logarithmic reduction was 6.15 and 6.54 respectively. On iPads for the MRSA strain of *Staph. aureus* at 10- and 15-minutes, the average logarithmic reduction was 5.59 and 5.73 respectively. Resistance to methicillin did not provide any increase in susceptibility to UV light.

The average logarithmic reduction of *Sal. enterica* on iPhones for 10- and 15-minutes was 5.32 and 5.89 respectively. The average logarithmic reduction of *Sal. enterica* on iPads for 10- and 15-minutes was the logarithmic reduction 4.39 and 5.18 respectively.

The average logarithmic reduction of *E. coli* on iPhones for 10- and 15-minutes was 6.69 and 6.79 respectively. On iPads the average logarithmic reduction of *E. coli* for 10- and 15-minutes was 6.41 and 6.60 respectively.

Of the microbes tested, *E. coli* was the most sensitive bacterium to the UV treatment and *Sal. enterica* was the most resistant.

Because of the various sizes and shapes of the household items, some of them, such as the headphones, were closer to the UV-C source than smaller items such as the tweezers and glasses. Since the intensity of the UV-C light irradiating an object is inversely proportional to the square of the distance from the UV-C source, the closer to the UV-C source an item is placed, the more effective the UV-C light is in killing bacteria. Glasses were placed in the HomeSoap device with the bows folded back. This resulted in the lens being at a slight angle to the UV-C light which in addition to being one of the items furthest from the UV-C lamp also reduced the effectiveness of the UV-C light in killing bacteria. These results are dramatically illustrated in Figures 1 and 2.

The average logarithmic reduction for *Staph. aureus* at 10- and 15-minutes was 5.76 and 5.58. The average logarithmic reduction for MRSA at 10- and 15-minutes was 5.42 and 5.79. The average

logarithmic reduction for *Sal. enterica* at 10- and 15-minutes was 4.27 and 4.81. The average logarithmic reduction for *E. coli* at 10- and 15-minutes was 6.09 and 6.73.

Overall, *Sal. enterica* was the most resistant to UV-C light and *E. coli* was the most sensitive. *Staph. aureus* and the MRSA strain of *Staph. aureus* were similar in their sensitivity to UV-C light.

Table 17. Results from UV-C and Ozone Testing

10.	Ultraviolet radiation	UL 1431, CLs. 83.1	Emission of ultraviolet radiation from the appliance was evaluated in accordance with the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values and Biological Indices. No UV light (less than 0.1 microwatt/cm ² was detected.) See attached photos.	Report was issued by Blackrock Consulting Services.
11.	Protection from ozone emissions	UL 1431, CLs. 83.2	Less than 0.000 ppm were detected. See attached photos	Report was issued by Blackrock Consulting Services

No detectable leakage of UV-C light was detected. No detectable ozone was produced during the ten-minute treatment.



Fig. 3 UV-C Measurement 1



Fig. 4 UV-C light meter 1



Fig. 5 Ozone meter in device 1



Fig. 6 0.000 readings from Ozone meter. 1

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