RESEARCH ON THE DISINFECTION OF A MOBILE DEVICE

Final report

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CONTENTS

1 INTRODUCTION

On February 2015, LED Suutari Oy requested the Department of Environmental Sciences at the University of Eastern Finland to inspect the power of a device intended to disinfect mobile devices and destroy microbes. The test results are presented in this report.

2 MATERIAL AND METHODS

2.1 Growing bacteria

E. coli (phase ATCC 13706) represented the bacterial indicator of fecal origins. The bacterium was inoculated from 3 ml of refrigerated growth medium into 100 ml of phage TYG broth (10 g of tryptone, 5 g of yeast extract, 2 g of glucose, 5 g of NaCl 5 g, MgSO4 · 7H2O 0.25 g /1000 ml deionized water), where the bacterium grew for 2 hours in the temperature of 37 °C. A 10-fold dilution of the suspension was made with sterile deionized water (1 ml of bacterial suspension + 9 ml of water) and the dilution was used to engraft the surface of the phone. The volume was defined before and after the UV treatment by dilution method for the culture with TYG agar (5 g of tryptone, 2.5 g of yeast extract, 1.0 g of glucose, 12 g of agar /1000 ml deionized water, growth in 37 °C, approximately 21 h) by using two parallel dishes/dilution (Koivunen & Heinonen-Tanski 2005).

Bacillus licheneformis/aerius (phase B2) represented a spore-forming bacterium. The bacterium was grown on solid culture medium (10 g of glucose, 5 g of peptone, 4.5 g of yeast extract, 12 g of agar/1000 ml water) for 24 hours in 37 °C and the growth dish was stored in room temperature and a refrigerator in order to form spores. Part of the growth was moved into 9 ml of sterile water and the volume of spores was measured with a Fuchs-Rosenthal counting chamber (Hirschmann EM Techcolor). A hundred-fold dilution of the suspension was made with sterile deionized water and the dilution was used to engraft the surface of the phone. The volume was defined before and after the UV treatment with dilution method for the culture in the aforementioned solid growth medium (growth in 37 °C for 24 hours) by using two parallel dishes/dilution.

Coliphage (phase no 6) extracted from municipal waste water represented the viruses, since it has proven to be very resistant to UV light in our earlier studies (Zyara et al. 2015). Coliphages are viruses that infect *E. coli*, and they are often used similarly to *E. coli* as indicators of fecal pollution. The coliphage growth, that had been kept refrigerated in phage TYG broth, was inoculated into 3 ml of fresh phage TYG broth consisting of host bacteria (*E. coli* phase ATCC 15597), in which the phage was grown for 4-5 h (37°C). The suspension was stored in a refrigerator for 24 h, and the phages were extracted from the host bacterium by centrifugation (3250 x *g*, 15 min). A ten-fold dilution was made of the phage fraction with sterile deionized water and the dilution was used to engraft the surface of the phone. The phage level was defined before and after the UV treatment from the dilutions of the sample by double-layer technique, where the hard phage TYG agar was covered with sample, color liquid (triphenyltetrazolium chloride) and a soft phage TYG-agar (ISO 1995), which includes host bacteria. After growth (37 °C, approximately 21 h), plaques on the host bacteria population that were caused by the phage were counted from the dish.

2.2 Disinfection tests

Separate engrafting tests were carried out for the inspected bacteria. A Lumia 530 phone was disinfected carefully by wiping it with 70% ethanol. After the surface had dried off, 0.1 ml of diluted microbe suspension was applied to the identified surface area of the phone. The suspension was drained on the glass surface by spreading it with a sterile glass stirrer. The disinfection power was examined both on the front and back side of the phone and the corresponding areas and drainage

times were as follows: front side 44.5 cm^2 – drainage time approximately 3 min, and back side 27.9 cm^2 – drainage time approximately 6 min.

The phone engrafted with bacterium was placed into the disinfection device and the lid was closed. Disinfection was started, and the device was switched off after the time of exposure. The inspected exposure times were 0 min (initial situation prior to disinfection), 2, 4, 6, 10, 15, 20, 25 and 30 minutes. After the treatment, the bacteria were wiped off of the surface of the phone with a sterile cotton bud dampened with water, from which the bacteria were separated into 4 ml of deionized water. A dilution series of the suspension was made with sterile deionized water (1 ml of bacterial suspension + 9 ml of water) and the bacteria was cultured on two parallel agar dishes as described in chapter 2.1. The phone was disinfected with 70 % of ethanol in between each treatment and was re-engrafted for the next treatment. Two parallel tests were carried out on the disinfection of both front and back side, and both were examined in a third parallel test by using three to five most reasonable exposure times.

The effect of the drainage on the destruction of bacteria was examined in one test, where the bacteria were engrafted on the front side of the phone, the phone was kept in the device without UV treatment and the bacteria was engrafted after the aforementioned exposure times as in the UV tests.

2.3. Calculating the results

After each test, the exposure times were counted as a function of microbe density (cfu/cm^2 = units forming colonies/cm^2 or pfu/cm^2 = units forming plaque/cm^2) as a weighted mean of dilutions and parallel dishes. The logarithmic destruction of microbes (Log^{10}) was counted by the scale

Logarithmic destruction = *Log*10*(Nb/Na)*

where the Nb = microbe density (cfu/cm^2) after the treatment and Na = microbe density (cfu/cm^2) before the treatment.

If the microbes could not be discovered by culture, the result is represented below the time of definition. When calculating the microbe reductions from the results that are below the definition limit, a half of the definition limit was used (= definition limit/2) in order to receive a numerical value to calculate the logarithmic results and to draw figures.

In order to determine the actual destruction caused by the UV treatment of the device, bacterial destruction caused by drainage was subtracted from the results. The final results are presented in geometric averages and dispersions of different tests.

3 RESULTS

3.1 *E. coli*

3.1.1 Front side of the phone

The level of engrafted *E. coli* on the front surface of the phone prior to the treatment was the average of 179 cfu/cm^2 in three parallel tests (0 min, Table 1). The destruction of *E. coli* on the front surface was efficient even after a four-minute treatment, after which the bacteria could no longer be detected by culture in two out of three parallels.

Table 1. The level of *Escherichia coli* (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) during 30 minutes of UV-Led exposure.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (8 Apr 2015)	249	0.18	0.09	0.04	0.09	0.04	<0.04[a]	<0.04	<0.04
2 (13 Apr 2015)	163	0.18	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
3 (16 Apr 2015)	140	0.18	<0.04	<0.04	nd[b]	nd	nd	nd	nd
Average$_{geom}$	**179**	**0.18**	**0.04**	**0.04**	**0.06**	**0.04**	**<0.04**	**<0.04**	**<0.04**
Dispersion$_{sd}$	57	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00
Minimum	140	0.18	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Maximum	249	0,18	0.09	0.04	0.09	0.04	<0.04	<0.04	<0.04
Median	163	0.18	<0.04	<0.04	0.07	0.04	<0.04	<0.04	<0.04

[a] The lowest definition limit of the method, i.e. the lowest level that could be defined from the front surface of the mobile device (44.5 cm^2) is 0.04 cfu/cm^2. Mark <0.04 indicates that *E. coli* could not be detected by culture.
[b] nd = not defined.

In the final reductions (Table 2), the destruction caused by the drainage (Table 3) was subtracted from the microbe densities of Table 1. The drainage was clearly not time responsive, and therefore the average destruction caused by the different exposure times (0.63, Table 3) was subtracted from the results.

Table 2. The logarithmic reduction of *Escherichia coli* (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) due to the impact of the UV Led during 30 minutes. The average impact of the drainage, presented in Table 3, was subtracted from the reductions.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (8 Apr 2015)	0.00	2.51	2.81	3.11	2.81	3.11	>3.41[a]	>3.41	>3.41
2 (13 Apr 2015)	0.00	2.33	>3.23	>3.23	>3.23	>3.23	>3.23	>3.23	>3.23
3 (16 Apr 2015)	0.00	2.26	>3.16	>3.16	nd[b]	nd	nd	nd	nd
Average$_{geom}$	**0.00**	**2.36**	**3.06**	**3.17**	**3.01**	**3.17**	**>3.32**	**>3.32**	**>3.32**
Dispersion$_{sd}$	0.00	0.13	0.22	0.06	0.30	0.08	0.13	0.13	0.13
Minimum	0.00	2.26	2.81	3.11	2.81	3.11	>3.23	>3.23	>3.23
Maximum	0.00	2.51	>3.23	>3.23	>3.23	>3.23	>3.41	>3.41	>3.41
Median	0.00	2.33	3.16	3.16	3.02	3.17	3.32	3.32	3.32

[a] The largest logarithmic reduction that can be defined by this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.
[b] nd = not defined.

Table 3. The level of *Escherichia coli* (cfu/cm^2) and the logarithmic reduction (cfu/cm^2) of the level on the front surface of the mobile device (A=44.5 cm^2) due to the impact of drainage during 30 minutes.

	Exposure time, min									
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**Average**
Level (cfu/cm^2)	249	36	108	26	37	71	147	58	62	88
Log-reduction (cfu/cm^2)	0.00	0.85	0.36	0.99	0.83	0.55	0.23	0.63	0.61	0.63

3.1.2 Back side of the phone

The engrafted *E. coli* level on the back surface of the phone prior to the treatment was the average of 2142 cfu/cm^2 in three parallel tests (0 min, Table 4). *E. coli* could not be discovered by culture in either test after 20 minutes of exposure.

Table 4. The level of Escherichia coli (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm 2) during 30 minutes of UV-Led exposure.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (13 Apr 2015)	430	3	0.29	0.65	<0.07	<0.07	<0.07	<0.07	<0.07
2 (16 Apr 2015)	6237	108	22	3	0.07	0.29	<0.07	<0.07	<0.07
3 (16 Apr 2015)	3662	102	5	1	nd	nd	nd	nd	nd
Average$_{geom}$	**2142**	**33**	**3**	**1**	**0.07**	**0.14**	**<0.07**	**<0.07**	**<0.07**
Dispersion$_{sd}$	2909	59	12	1	0.00	0.15	0.00	0.00	0.00
Minimum	430	3	0.29	0.65	<0.07	<0.07	<0.07	<0.07	<0.07
Maximum	6237	108	22	3	0.07	0.29	<0.07	<0.07	<0.07
Median	3662	102	5	0.98	0.07	0.17	<0.07	<0.07	<0.07

a The lowest definition limit of the method, i.e. the lowest level that could be defined from the front surface of the mobile device (27.9 cm^2) is 0.07 cfu/cm^2. Mark <0.07 indicates that *E. coli* could not be detected by culture.
b nd = not defined.

In the final reductions on the back side (Table 5), destruction caused by the drainage (Table 6) was subtracted from the microbe densities of Table 4. The drainage was clearly not time responsive, thus the average destruction caused by the different exposure times (0.4, Table 6) was subtracted from the results.

Table 5. The logarithmic reduction of *Escherichia coli* (cfu/cm^2) on the back surface of the mobile device (A=44.5 cm^2) due to the impact of UV Led during 30 minutes. The reductions have been subtracted from the average impact of drainage, presented in Table 6.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (13 Apr 2015)	0.00	1.72	2.78	2.43	>3.68	>3.68	>3.68	>3.68	>3.68
2 (16 Apr 2015)	0.00	1.37	2.05	2.87	4.45	3.94	>4.84	>4.84	>4.84
3 (16 Apr 2015)	0.00	1.39	2.75	3.41	nd	nd	nd	nd	nd
Average$_{geom}$	0.00	**1.48**	**2.50**	**2.87**	**4.09**	**3.81**	**>4.22**	**>4.22**	**>4.22**
Dispersion$_{sd}$	0.00	0.20	0.41	0.49	0.61	0.18	0.82	0.82	0.82
Minimum	0.00	1.37	2.05	2.43	3.68	3.68	>3.68	>3.68	>3.68
Maximum	0.00	1.72	2.78	3.41	4.54	3.94	>4.84	>4.84	>4.84
Median	0.00	1.39	2.75	2.87	4.11	3.81	4.26	4.26	4.26

[a] The largest logarithmic reduction that can be defined by this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.

[b] nd = not defined

Table 6. The level of *Escherichia coli* (cfu/cm^2) and the level's logarithmic reduction (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) due to the impact of drainage during 30 minutes.

	Exposure time, min									
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**Average**
Level (cfu/cm^2)	580	910	286	212	190	165	231	164	132	319
Log-reduction (cfu/cm^2)	0.00	-0.20	0.31	0.44	0.48	0.55	0.40	0.55	0.64	0.40

3.1.3 Summary

The average logarithmic reductions of *E. coli* levels on the front and back side of the phone are presented in Figure 1. The reduction of three logarithm units was reached after a four-minute-exposure on the front side of the phone and approximately after six minutes of exposure on the back side.

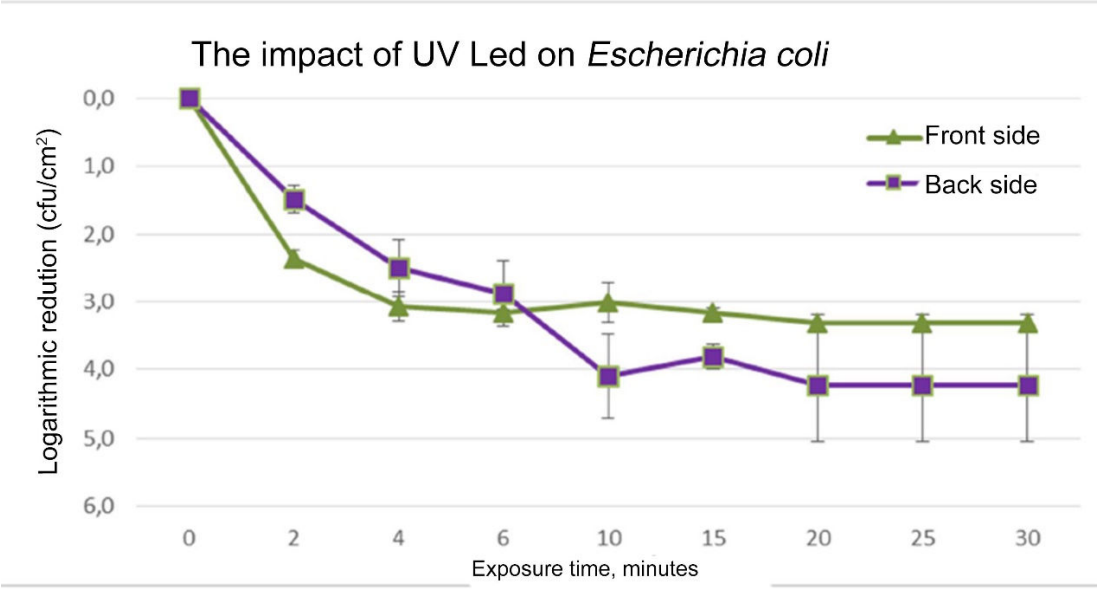

Figure 1. The impact of the UV-Led treatment on *E. coli* on the front and back surface of the phone. The maximum logarithmic reduction on the front side 3.3 and on the back side 4.4.

3.2 *Bacillus*

3.2.1 Front side of the phone

The engrafted *Bacillus* level on the front surface of the phone prior to the treatment was the average of 206 cfu/cm^2 in three parallel tests (0 min, Table 7). The destruction of *Bacillus* on the front surface of the phone was efficient already during the first minutes, and the destruction of three logarithm units was reached in 4 minutes (Table 8). The bacterium could not be discovered by culture after 15 minutes.

Table 7. The level of *Bacillus* (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) during 30 minutes of UV-Led exposure.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (20 Apr 2015)	507	1	<0.04	0.13	0.09	<0.04	<0.04	<0.04	<0.04
2 (21 Apr 2015)	132	1	0.25	<0.04	<0.04	<0.04	0.04	<0.04	<0.04
3 (21 Apr 2015)	132	1	0.12	0.09	nd	nd	nd	nd	nd
Average$_{geom}$	**206**	**0.98**	**0.11**	**0.08**	**0.06**	**<0.04**	**0.04**	**<0.04**	**<0.04**
Dispersion$_{sd}$	217	0.31	0.10	0.04	0.03	0.00	0.00	0.00	0.00
Minimum	132	0.69	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Maximum	507	1	0.25	0.13	0.09	<0.04	0.04	<0.04	<0.04
Median	132	1	0.12	0.09	0.07	<0.04	0.04	<0.04	<0.04

[a] The lowest definition limit of the method, i.e. the lowest level that could be defined from the front surface of the mobile device (44.5 cm^2) is 0.04 cfu/cm^2. Mark <0.04 indicates that *Bacillus* could not be detected by culture.

[b] nd = not defined.

Table 8. The logarithmic reduction of *Bacillus* (cfu/cm^2) on the front surface of the mobile device (A=44.5cm^2) for the impact of UV Led during 30 minutes. The level of bacteria did not decrease due to the drainage, so the impact of drainage was not subtracted from the results.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (20 Apr 2015)	0.00	2.70	>4.35	3.57	3.57	>4.35	>4.35	>4.35	>4.35
2 (21 Apr 2015)	0.00	2.00	2.73	>3.77	>3.77	>3.77	>3.47	>3.77	>3.77
3 (21 Apr 2015)	0.00	2.28	3.03	3.17	nd	nd	nd	nd	nd
Average$_{geom}$	**0.00**	**2.31**	**3.30**	**3.49**	**3.76**	**>4.05**	**3.88**	**>4.05**	**>4.05**
Dispersion$_{sd}$	0.00	0.35	0.86	0.31	0.01	0.41	0.63	0.41	0.41
Minimum	0.00	2.00	2.73	3.17	3.75	>3.77	>3.47	>3.77	>3.77
Maximum	0.00	2.70	>4.35	>3.77	>3.77	>4.35	>4.35	>4.35	>4.35
Median	0.00	2.28	3.03	3.57	3.76	4.06	3.91	4.06	4.06

[a] The largest logarithmic reduction that can be defined with this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.
[b] nd = not defined.

3.2.2 Back side of the phone

The engrafted *Bacillus* level on the back surface of the phones prior to the treatment was the average of 515 cfu/cm^2 in three parallel tests (0 min, Table 9). *Bacillus* could be discovered by culture aside from exposure times longer than 30 minutes on 21 April 2015.

Table 9. The level of *Bacillus* (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) during 30 minutes of UV-Led exposure.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (20 Apr 2015)	230	160	24	12	5	1	0.39	0.14	0.14
2 (21 Apr 2015)	1264	96	66	9	7	0.59	0.72	0.72	<0.07
3 (21 Apr 2015)	469	105	15	5	2	0.43	nd	nd	nd
Average$_{geom}$	**515**	**117**	**28**	**8**	**4**	**0.70**	**0.53**	**0.32**	**0.10**
Dispersion$_{sd}$	541	35	28	4	2	0.50	0.23	0.41	0.05
Minimum	230	96	15	5	2	0.43	0.39	0.14	<0.07
Maximum	1264	160	66	12	7	1	0.72	0.72	0.14
Median	469	105	24	9	5	0.59	0.55	0.43	0.11

[a] The lowest definition limit of the method, i.e. the lowest level that could be defined from the back surface of the mobile device (27.9 cm^2) is 0.07 cfu/cm^2. Mark <0.07 indicates that *Bacillus* could not be detected by culture.
[b] nd = not defined.

In the final reductions of the back side (Table 10), the destruction caused by drainage (Table 11) was subtracted from the microbe densities of Table 9. The drainage was clearly not time responsive, and therefore the average destruction caused by the different exposure times (0.16,

Table 12) have been subtracted from the results. The destruction of three logarithmic units was reached in 25 minutes on average (Table 10).

Table 10. The logarithmic reduction of *Bacillus* (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) due to the impact of UV Led during 30 minutes. The reductions have been subtracted from the average impact of the drainage, presented in Table 11.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (20 Apr 2015)	0.00	0.02	0.85	1.15	1.51	2.09	2.63	3.07	3.07
2 (21 Apr 2015)	0.00	0.98	1.14	2.01	2.14	3.19	3.11	3.11	>4.41
3 (21 Apr 2015)	0.00	0.51	1.37	1.85	2.20	2.90	nd	nd	nd
Average$_{geom}$	**0.00**	**0.21**	**1.10**	**1.62**	**1.93**	**2.68**	**2.86**	**3.09**	**3.68**
Dispersion$_{sd}$	0.00	0.48	0.26	0.46	0.38	0.57	0.34	0.03	0.95
Minimum	0.00	0.02	0.85	1.15	1.51	2.09	2.63	3.07	3.07
Maximum	0.00	0.98	1.37	2.01	2.20	3.19	3.11	3.11	>4.41
Median	0.00	0.51	1.14	1.85	2.14	2.90	2.87	3.09	3.74

[a] The largest logarithmic reduction that can be defined with this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.
[b] nd = not defined.

Table 11. The level of *Bacillus* (cfu/ cm^2) and the logarithmic reduction (cfu/ cm^2) on the back surface of the mobile device (A=27.9 cm^2) during 30 minutes of UV-Led exposure.

	Exposure time, min									
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**Average**
Level (cfu/cm^2)	4034	2502	3604	3102	2333	3369	2581	2802	2463	2977
Log-reduction (cfu/cm^2)	0.00	0.21	0.05	0.11	0.24	0.08	0.19	0.16	0.21	0.16

3.2.3 Summary

The average logarithmic reductions of *Bacillus* levels on the front and back side of the phone are presented in Figure 2. The reduction of three logarithm units was reached after a four-minute-treatment on the front side of the phone and approximately after 25 minutes of treatment on the back side.

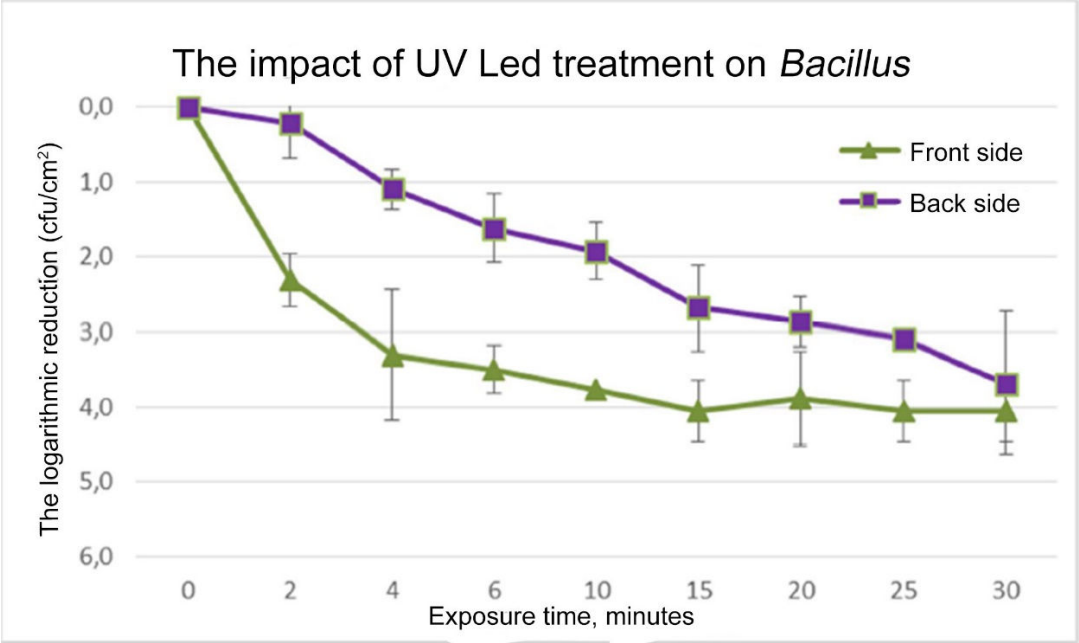

Figure 2. The effect of the UV Led process on the *Bacillus* on the front and back surface of the phone. The maximum logarithmic reduction is on the front and back side 4.1.

3.3 Coliphage

3.3.1 Front side of the phone

The engrafted coliphage level on the front surface of the phone prior to the treatment was the average of 77 cfu/cm^2 in three parallel tests (0 min, Table 12). The destruction of coliphage was rather efficient on the front surface, and no coliphage was detected after 10 minutes of treatment.

Table 12. The level of coliphage (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) during a 30-minute exposure of UV-Led.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (25 Apr 2015)	41	5	2	0.20	<0.04	<0.04	<0.04	<0.04	<0.04
2 (26 Apr 2015)	70	5	0.27	0.09	<0.04	<0.04	<0.04	<0.04	<0.04
3 (27 Apr 2015)	157	2	0.18	0.04	nd	nd	nd	nd	nd
Average$_{geom}$	**77**	**4**	**0.44**	**0.09**	**<0.04**	**<0.04**	**<0.04**	**<0.04**	**<0.04**
Dispersion$_{sd}$	60	1	0.89	0.08	0.00	0.00	0.00	0.00	0.00
Minimum	41	2	0.18	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Maximum	157	5	2	0.20	<0.04	<0.04	<0.04	<0.04	<0.04
Median	70	5	0.27	0.09	<0.04	<0.04	<0.04	<0.04	<0.04

[a] The lowest definition limit of the method, i.e. the lowest level that could be defined from the front surface of the mobile device (44.5 cm^2) is 0.04 cfu/cm^2. Mark <0.04 indicates that coliphage could not be detected by culture.

[b] nd = not defined.

In the final reductions (Table 13), the microbe densities of Table 12 were subtracted of the coliphage destruction caused by the drainage (Table 4). The drainage was clearly not time responsive, thus the average destruction caused by the different exposure times (0.72, Table 14) has been subtracted from the results.

Table 13. The logarithmic reduction of coliphage (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) for the impact of the UV Led during 30 minutes. The reductions have been subtracted from the average impact of the drainage, presented in Table 14.

Parallel (date)	**Exposure time, min**								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (25 Apr 2015)	0.00	0.20	0.65	1.59	>2.55	>2.55	>2.55	>2.55	>2.55
2 (26 Apr 2015)	0.00	0.47	1.70	2.17	>2.78	>2.78	>2.78	>2.78	>2.78
3 (27 Apr 2015)	0.00	1.08	2.22	2.83	nd	nd	nd	nd	nd
Average$_{geom}$	**0.00**	**0.47**	**1.35**	**2.14**	**>2.66**	**>2.66**	**>2.66**	**>2.66**	**>2.66**
Dispersion$_{sd}$	0.00	0.45	0.80	0.62	0.16	0.16	0.16	0.16	0.16
Minimum	0.00	0.20	0.65	1.59	>2.55	>2.55	>2.55	>2.55	>2.55
Maximum	0.00	1.08	2.22	2.83	>2.78	>2.78	>2.78	>2.78	>2.78
Median	0.00	0.47	1.70	2.17	>2.66	>2.66	>2.66	>2.66	>2.66

[a] The largest logarithmic reduction that can be defined by this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.

[b] nd = not defined.

Table 14. The level of coliphage (cfu/cm^2) and the level's logarithmic reduction (cfu/cm^2) on the front surface of the mobile device (A=44.5 cm^2) on the impact of drainage during 30 minutes.

	Exposure time, min									
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**Average**
Level (cfu/cm^2)	319	207	265	46	56	79	29	38	16	92
Log-reduction (cfu/cm^2)	0.00	0.19	0.08	0.84	0.75	0.60	1.05	0.92	1.30	0.72

3.3.2 Back side of the phone

The engrafted coliphage level on the back surface of the phones prior to the treatment was the average of 453 cfu/cm^2 in three parallel tests (0 min, Table 15). Coliphage could not be discovered by culture in either test after 25 minutes of treatment.

Table 15. The level of coliphage (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) during 30 minutes of UV-Led exposure.

Parallel (date)	Exposure time, min								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (25 Apr 2015)	487	122	4	2	3	0.36	0.36	<0.07	<0.07
2 (26 Apr 2015)	380	143	8	10	1	<0.07	<0.07	<0.07	<0.07
3 (27 Apr 2015)	502	183	13	9	1	nd	nd	nd	nd
Average$_{geom}$	**453**	**147**	**7**	**6**	**1**	**0.16**	**0.16**	**<0.07**	**<0.07**
Dispersion$_{sd}$	67	31	5	4	0.97	0.20	0.20	0.00	0.00
Minimum	380	122	4	2	0.72	0.04	0.04	<0.07	<0.07
Maximum	502	183	13	10	3	0.36	0.36	<0.07	<0.07
Median	487	143	8	9	1	0.22	0.22	<0.07	<0.07

[a] The lowest definition limit of the method, i.e. the lowest level that could be defined from the back surface of the mobile device (27.9 cm^2) is 0.07 cfu/cm^2. Mark <0.07 indicates that coliphage could not be detected by culture.
[b] nd = not defined.

In the final reductions of the back side (Table 16), the microbe densities of Table 15 were reduced of the destruction caused by the drainage (Table 17). The drainage was clearly not time responsive, thus the results have been reduced of the average destruction caused by the different exposure times (0.31, Table 17).

Table 16. The logarithmic reduction of coliphage (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) for the impact of UV Led during 30 minutes. The reductions have been subtracted from the average impact of the drainage, presented in Table 17.

Parallel (date)	Exposure time, min								
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**
1 (25 Apr 2015)	0.00	0.29	1.78	1.99	1.97	2.82	2.82	>3.82	>3.82
2 (26 Apr 2015)	0.00	0.11	1.38	1.26	2.41	>3.71	>3.71	>3.71	>3.71
3 (27 Apr 2015)	0.00	0.13	1.27	1.46	2.37	nd	nd	nd	nd
Average$_{geom}$	**0.00**	**0.16**	**1.46**	**1.54**	**2.24**	**3.24**	**3.24**	**3.77**	**3.77**
Dispersion$_{sd}$	0.00	0.10	0.27	0.38	0.24	0.63	0.63	0.08	0.08
Minimum	0.00	0.11	1.27	1.26	1.97	2.82	2.82	3.71	3.71
Maximum	0.00	0.29	1.78	1.99	2.41	3.71	3.71	3.82	3.82
Median	0.00	0.13	1.38	1.46	2.37	3.27	3.27	3.77	3.77

[a] The largest logarithmic reduction that can be defined with this method varies in the parallel tests based on the microbe density of the initial situation. Mark > signifies that the maximal reduction in the tests has been reached.
[b] nd = not defined.

Table 17. The level of coliphage (cfu/cm^2) and the level's logarithmic reduction (cfu/cm^2) on the back surface of the mobile device (A=27.9 cm^2) due to the impact of drainage during 30 minutes.

	Exposure time, min									
	0	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**Average**
Level (cfu/cm^2)	264	179	170	204	102	103	104	96	118	134
Log-reduction (cfu/cm^2)	0.00	0.17	0.19	0.11	0.41	0.41	0.41	0.44	0.35	0.31

3.3.3 Summary

The average logarithmic reductions of coliphage levels on the front and back side of the phone are presented in Figure 3. The maximum reduction was reached on the front side after ten minutes of treatment. The reduction of three logarithm units on the back side was reached after a fifteen minutes of treatment.

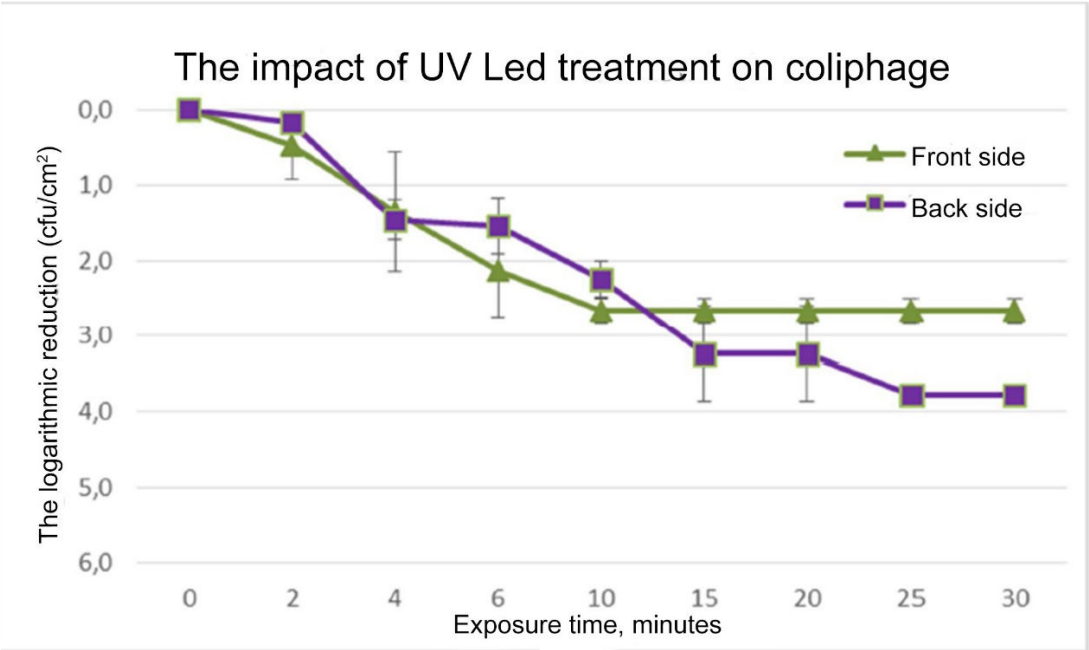

Figure 3. The impact of the UV Led process on coliphage on the front and back surface of the phone. The maximum logarithmic reduction on the front side 2.8 and on the back side 3.8.

4 CONCLUSION

Of all the examined microbes, the indicator microbe of fecal origin, *E. coli*, was destroyed the fastest. The destruction of three logarithmic units occurred on the front surface of the phone in four minutes and on the back side in ten minutes (Table 18). On the front surface of the phone, the *Bacillus*-spores were destroyed as fast as the *E. coli* spores, but as for the coliphage, which is known to be resistant to radiation produced by a traditional low-pressure UV lamp, the destruction was slower. Regarding all the examined microbes, the destruction took more time on the back side than the front side. This can be affected by e.g. the different way the UV radiation of the

disinfectant device is directed on the back surface, the different surface material of the back side and the different attachment of the microbes.

Table 18. The required times for the examined microbes on three logarithmic units in the UV-Led treatment.

	E. coli (min)	*Bacillus* (min)	Coliphage (min)
Front side	4	4	10[a]
Back side	10	25	15

a The largest logarithmic reduction that could be defined with this method was > 2.66.

E. coli proved to be more sensitive than *Bacillus*-spores or coliphage is an aligned result with the results of traditional UV light tests (Hijnen ym. 2006, Gerba 2015).

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