# Surface Micro-Discharge Plasma under different humidity and temperature

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# medical applications with plasma

## characteristics of plasma treatment

- mixture of several components (charged particles, reactive species, light, heat, etc.)

-->plasma can be designed for many purposes

- contact-free treatment
- treatment on rough surfaces

→ plasma for hygiene

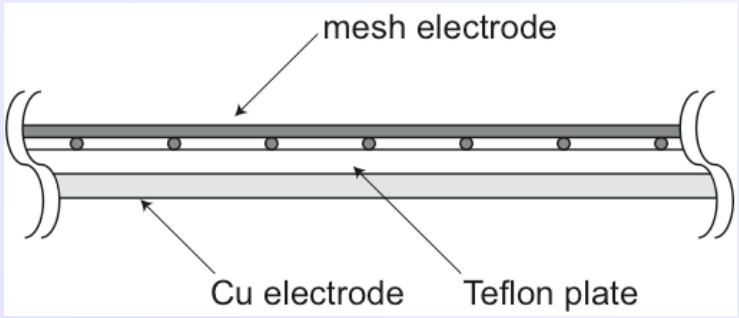
Hand washing with disinfectants – a tedious task (minutes)

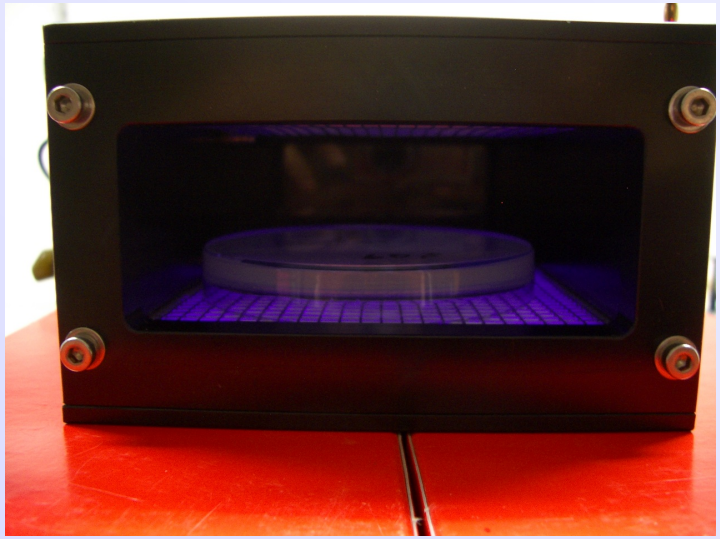
If used too often, there are skin irritations and allergies.





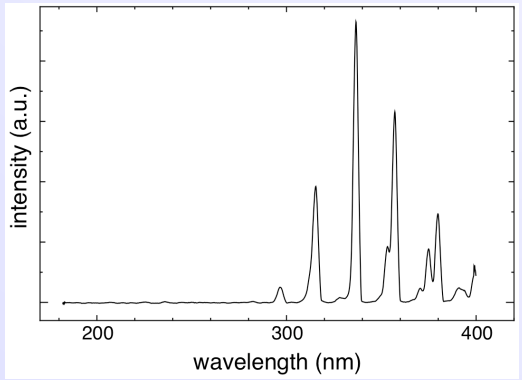

# Surface Micro-Discharge electrode



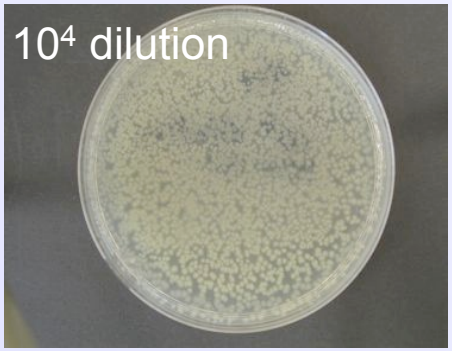
frequency: 12.5 kHz (sinusoidal)
voltage: 15~18 $kV_{pp}$
power: 0.5 $W/cm^2$
area: ~100 $cm^2$ for each

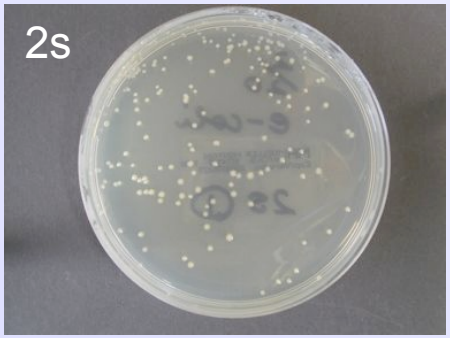
$O_3$: ~ a few ppm
$NO_2$: ~ 0.5 ppm

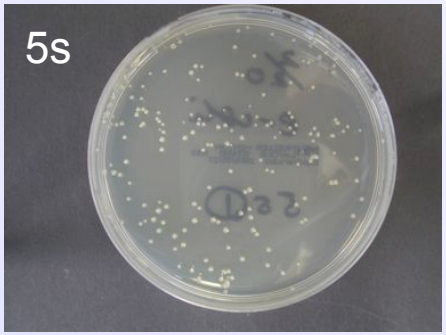


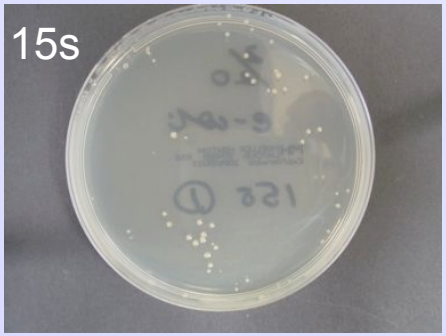

UV power:
0.43 μW/$cm^2$

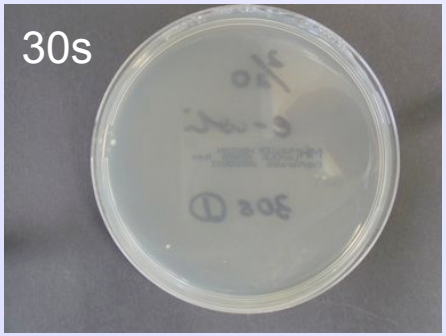
# bactericidal property



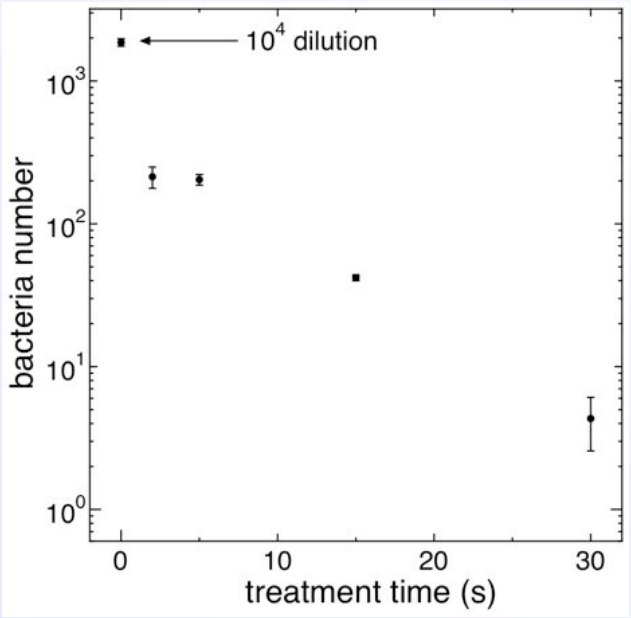



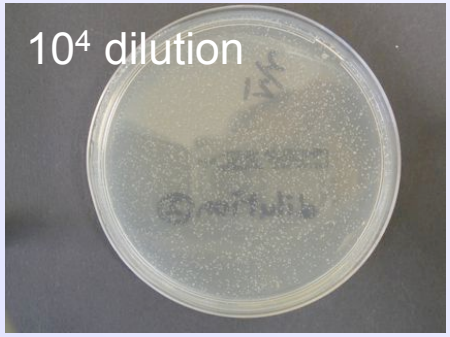



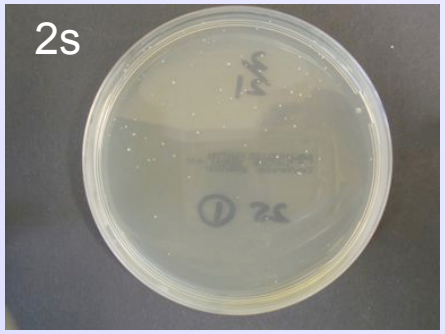

*Escherichia coli (g -ve)*

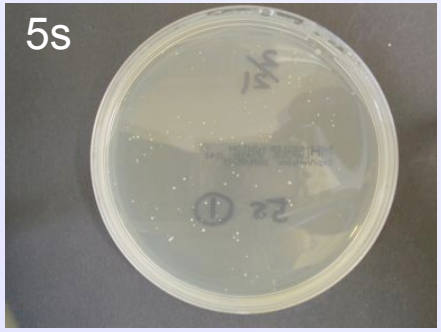


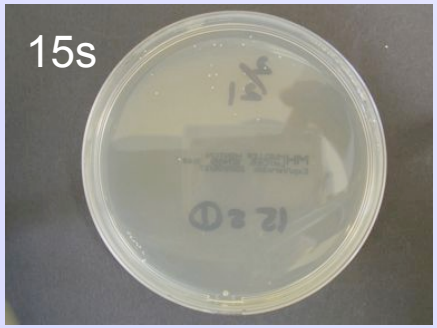

V = 18 $kV_{pp}$. 0.5 $W/cm^2$

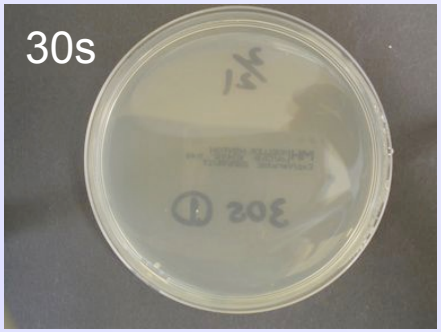
# bactericidal property



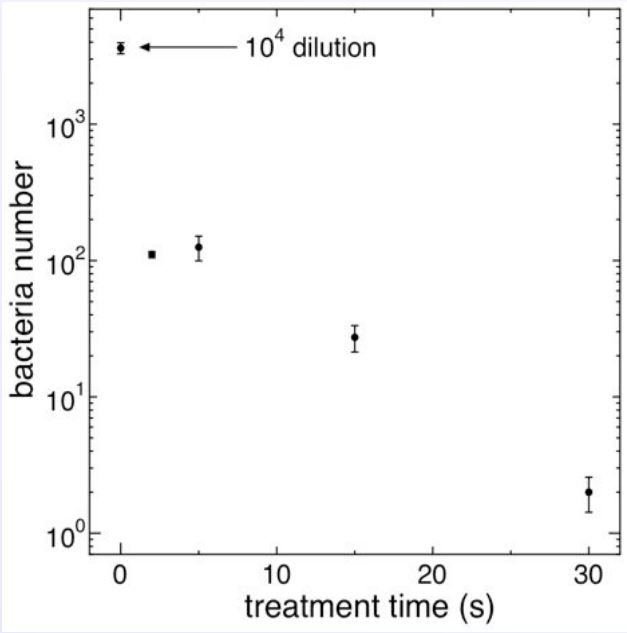



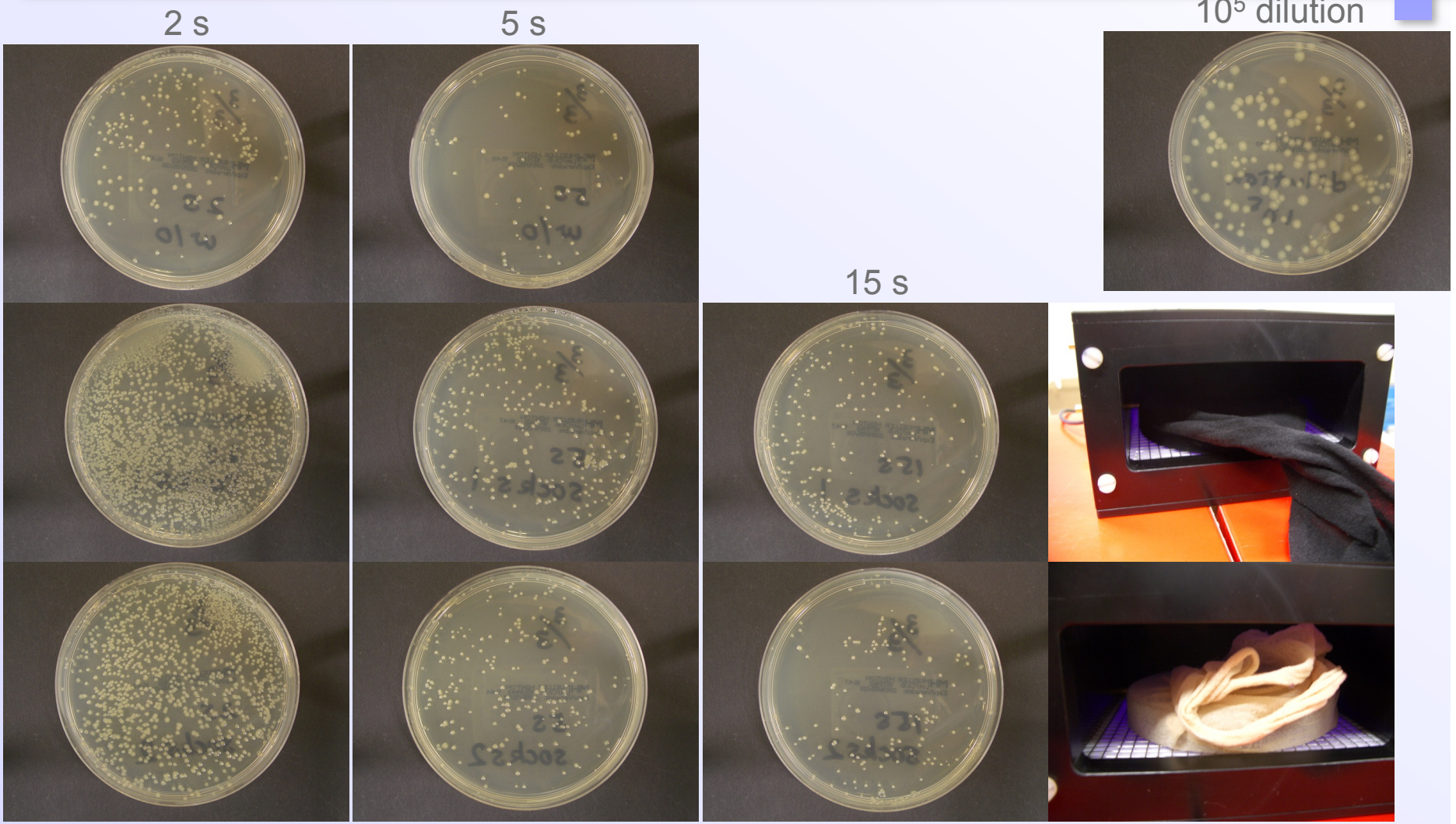




*Enterococcus (g +ve)*

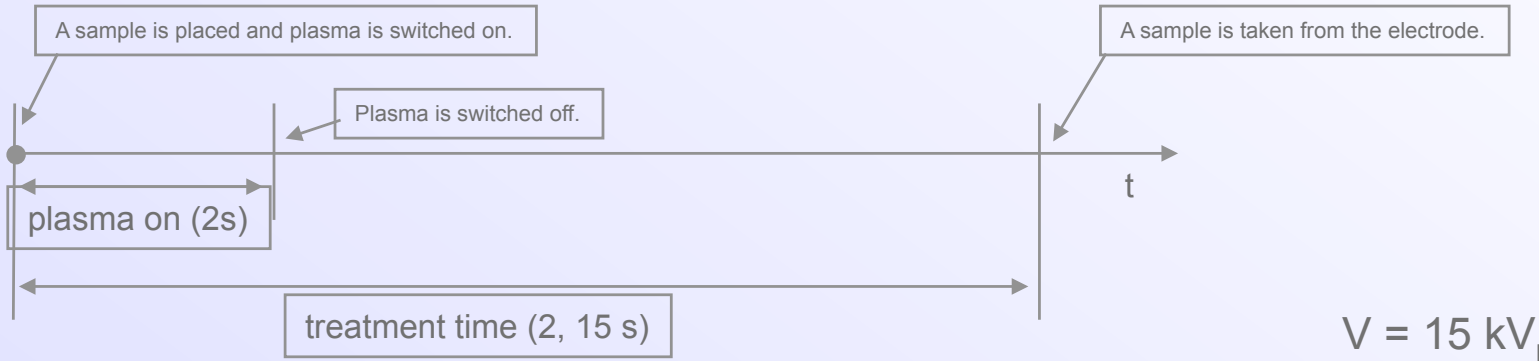



V = 18 $kV_{pp}$. 0.5 $W/cm^2$

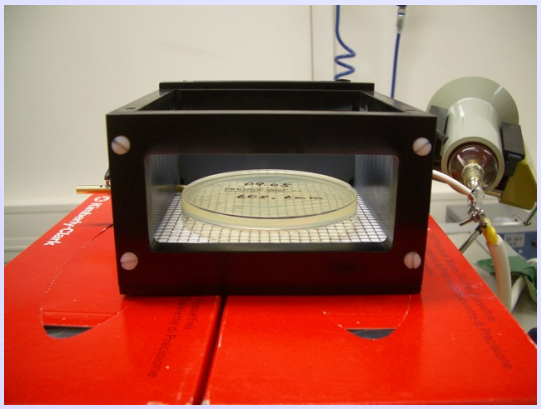
# through textile



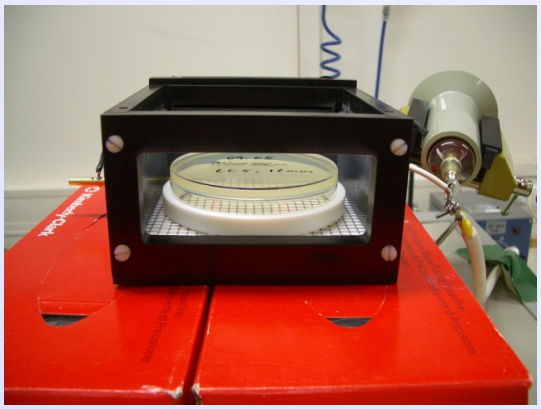
# afterglow effect



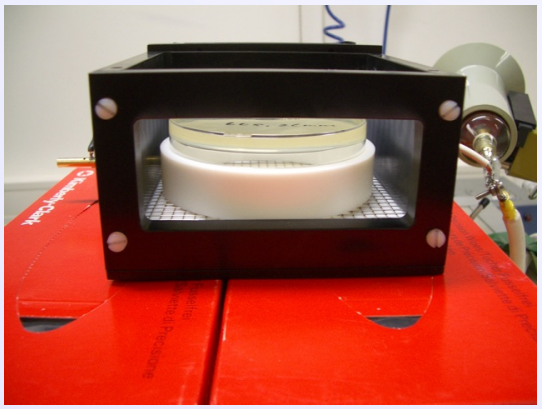

$V = 15\ kV_{pp}$. $0.4\ W/cm^2$



distance: 6 mm
volume: 35 $cm^2$



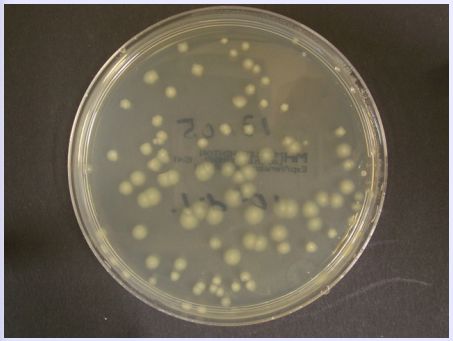
distance: 16 mm
volume: 93 $cm^2$

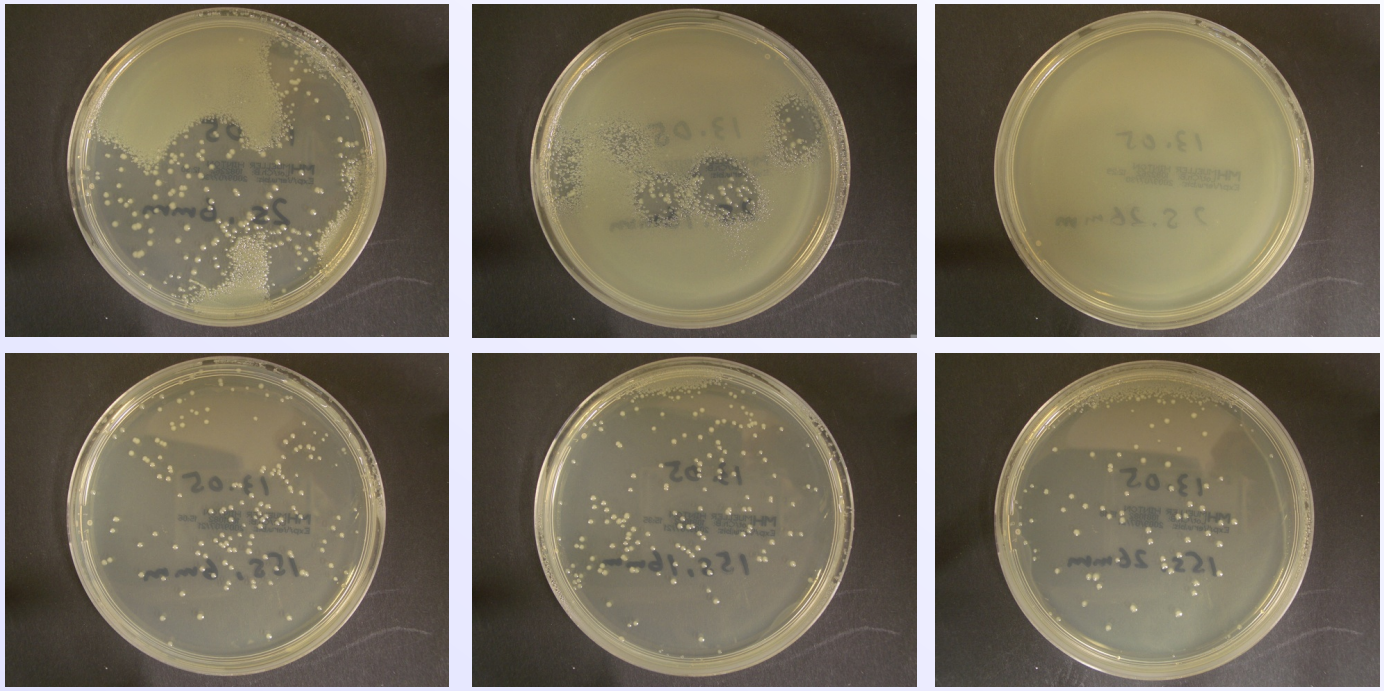


distance: 26 mm
volume: 151 $cm^2$

# afterglow effect

$10^5$ dilution

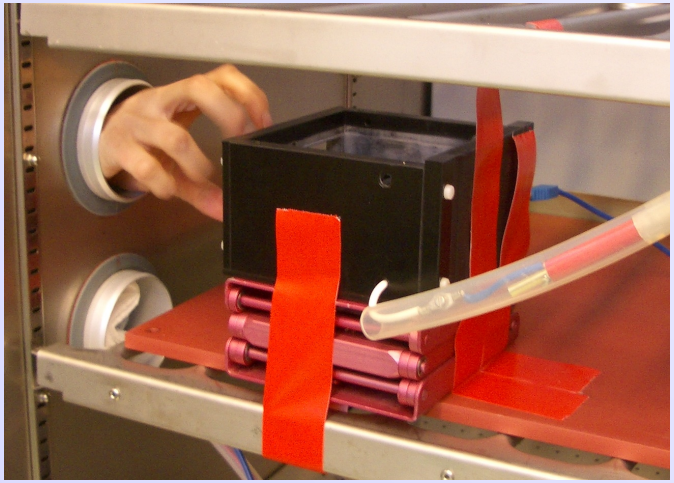





→ long lifetime species contribute to a bactericidal property.

V = 15 $kV_{pp}$. 0.4 $W/cm^2$

# environmental chamber



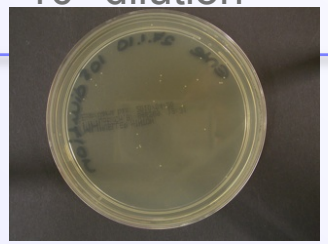
method:

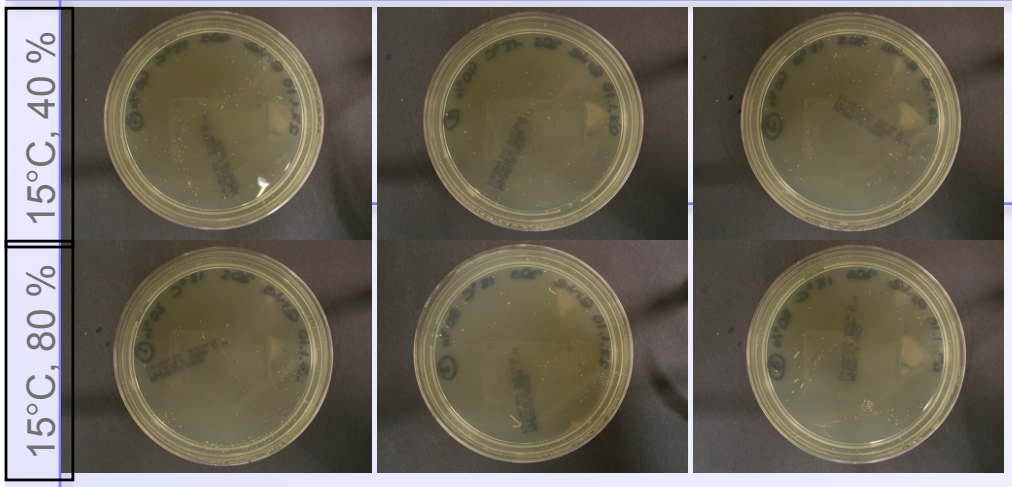
1. place 3 agar plates with bacteria in the environmental chamber
2. set the environmental condition and wait ~20 minutes
3. plasma treatment of *E.coli* for 30 seconds, *Enterococcus* for 15 seconds
4. take plates out of the chamber and incubate for 18 hours at 35 deg.

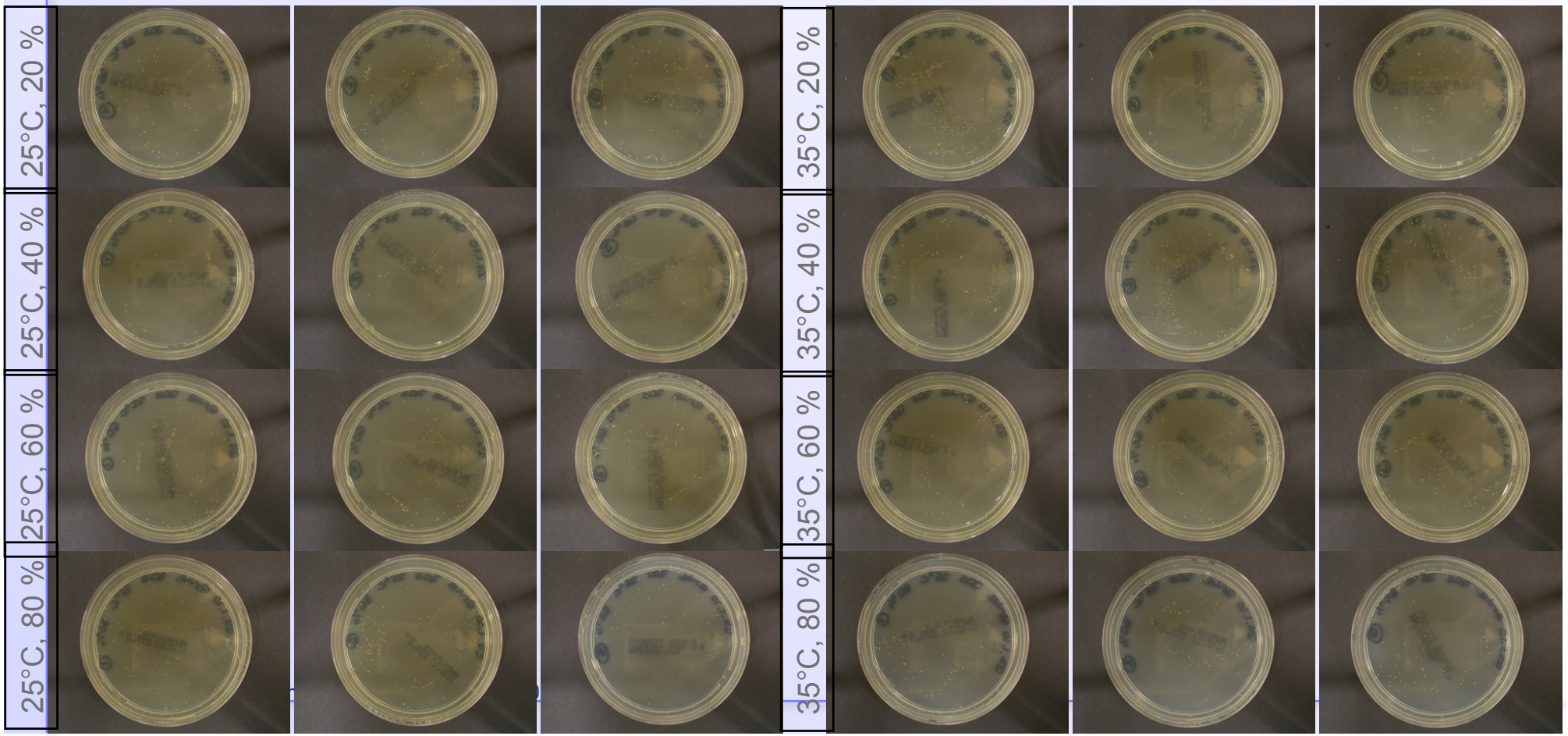
| | |
|---|---|
| temperature: | 15, 25, 35 °C |
| humidity: | 20, 40, 60, 80 % |
| voltage: | 15 $kV_{pp}$ |
| power: | 0.4 $W/cm^2$ |

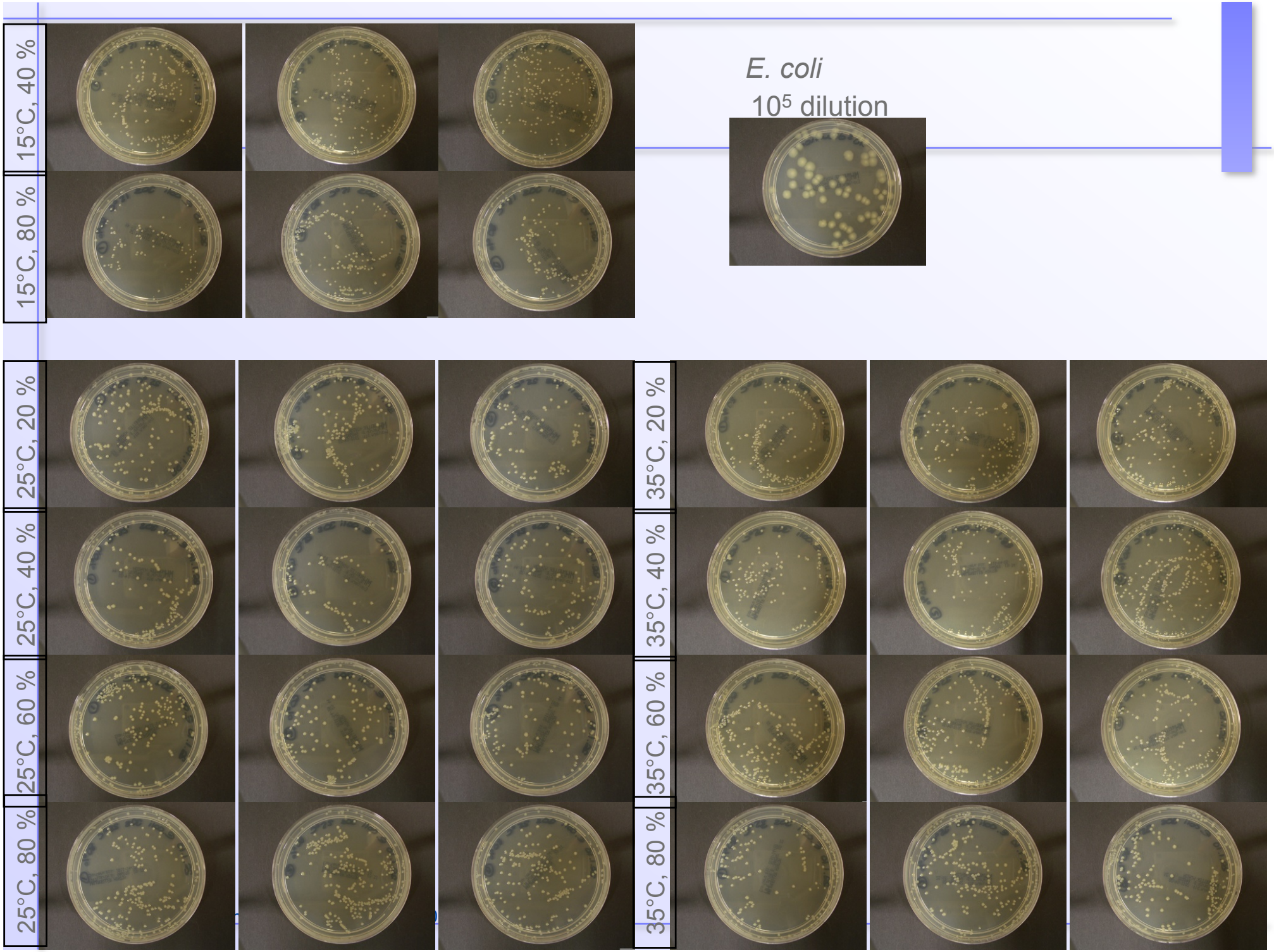
*Enterococcus*

$10^5$ dilution



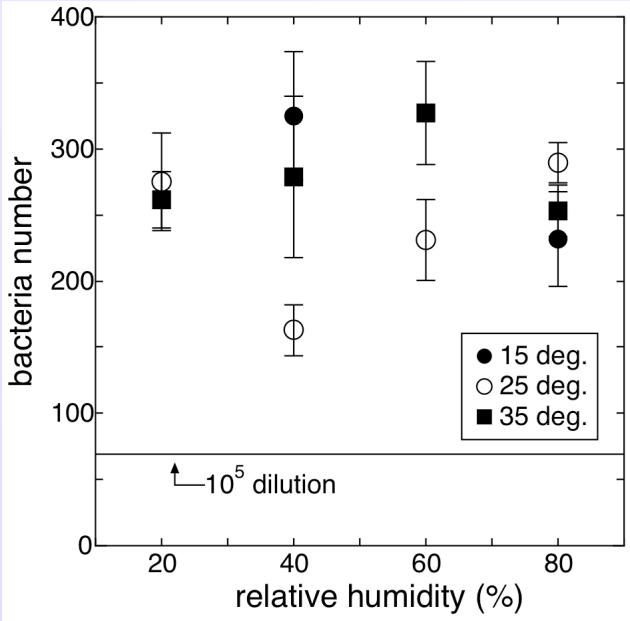


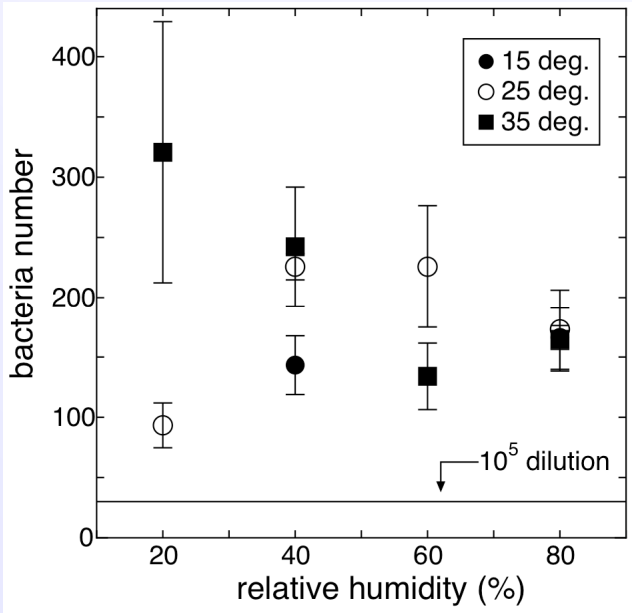

15°C, 40 %
15°C, 80 %
E. coli
10^5 dilution
25°C, 20 %
25°C, 40 %
25°C, 60 %
25°C, 80 %
35°C, 20 %
35°C, 40 %
35°C, 60 %
35°C, 80 %

# bactericidal effect in different ambient conditions

*Enterococcus (g +ve)*

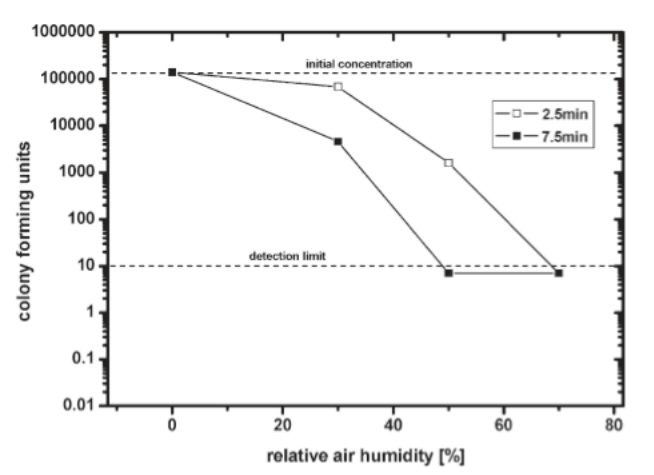



*Escherichia coli (g -ve)*



# change in humidity

*Bacillus atrophaeus*




M. Haehnel, T. von Woedke, K.-D. Weltmann
Plasma Process. Polym. **7** (2010) 244.

water vapour in plasma
➔production of OH radicals

•**bacteria**: no statistical difference in bactericidal property for different humidities.
•**spores**: humidity influences on reduction rate.

OH radicals alone are not the major candidate responsible for killing or inactivating bacteria
or
the mechanism for killing spores is different from killing bacteria.

# summary

1. Bactericidal properties of our SMD plasma dispenser under different ambient conditions.
2. A large range of different temperatures and relative humidities does not lead to a significant difference in bactericidal properties for both gram positive *Enterococcus Mundtii* and gram negative *Escherichia coli*.

- The measurements can give a hint on the dominant processes responsible for plasma disinfection.
- The SMD plasma dispenser is suitable for disinfection in hospitals and other public or private areas to reduce the spread of bacterial diseases.