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# Decontamination of the inner walls of a narrow tube at atmospheric pressure using long distance propagation discharge in argon

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Non-thermal plasma at atmospheric pressure is a useful tool for bio-decontamination because it produces reactive species (atoms, radicals, ions and stable species such as $O_3$ and $H_2O_2$) and UV emission, while temperature remains close to ambient. Therefore, non-thermal plasma technologies have been investigated for surface decontamination of thermally sensitive materials, in particular of small diameter tubes[1,2] that is of interest for medical applications. In this work, a pulsed corona discharge was propagated over 49 cm on the inner walls of a quartz tube (8 mm inner diameter) in which argon (Ar) was flowing at atmospheric pressure. A tungsten needle placed at the tube inlet was connected to a HV power supply that produced positive voltage pulses of up to 35 kV peak and 200 ns-5 µs duration at a rate of 500 pulses/s.


**Figure 1:** *Photograph of the argon pulsed discharge propagating over 49 cm tube*

*Escherichia coli* DH1 was used to evaluate the bactericidal effect; two droplets ($10^8$ bac./mL) were deposited on the tube inner surface, 2 and 44 cm from the HV electrode. In the case of pure Ar at 44 cm, 3 log reduction from the initial bacterial load was measured in 20 min; addition of 760 ppm of water in Ar enhanced the bactericidal effect to 4 log. We obtained full reduction (6 log) within 30 min of exposure in both cases. The effect of near UV emission (308 nm) alone was quantified by placing the bacteria on the outside surface of the quartz tube, and accounted for 7-48% of the plasma treatment bactericidal efficiency, depending on the sample condition (liquid/dry) and Ar water content. VUV (126 nm) is also expected to have an impact; however this was not quantified here. The effect of $H_2O_2$ was investigated; its aqueous concentration was 222 and 53 mg/L $H_2O_2$ at 2 and 44 cm, respectively, after 5 min exposure of water droplets to the humid Ar discharge. Incubation of bacterial cells in solutions with the same $H_2O_2$ concentrations for 5 min resulted in a 0.1 log reduction only (compared to 1.3 log with 5 min plasma exposure). The samples treated in Ar flow only controlled for the effect of anoxic conditions and desiccation accounted for less than 0.25 log reduction in 20 min. The temperature of the gas and quartz tube surface remained below 29°C. These results suggest that the major contributors to the measured bactericidal effect are OH radicals with synergistic effects with the secondary factors investigated in this study. Pulsed discharge plasma in argon is promising for bio-decontamination of inner walls of long tubes because it operates at atmospheric pressure without overheating the treated surfaces and does not produce toxic by-products such as ozone and nitrogen oxides.

[1] A-M. Pointu *et al.* Plasma Process. Polym. 5, 559–568 (2008)
[2] E. Odic *et al.* NATO ARW Plasma for bio-decontamination, medicine and food security, NATO ASI Series, Z. Machala et al. ed., Springer. 93-106 (2012)

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