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Bio-decontamination by DC Discharges in Atmospheric Air with Water

I. Jedlovský[1], Z. Machala[2], V. Martišovitš[2], L. Šikurová[1]

[1]Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University, Mlynska dolina, 84248 Bratislava, Slovakia
(e-mail: jedlovsky@fmph.uniba.sk)
[2]Department of Astronomy, Earth Physics and Meteorology, same address

Abstract

We tested bio-decontamination effects of three types of DC electrical discharges in atmospheric air with one electrode submerged in water on selected G- and G+ bacteria in solution. A substantial decrease of bacterial concentration was observed, especially in the transient spark. Emission spectroscopy indicates the major role of radicals and active species among other inactivation mechanisms.

Introduction

Non-thermal plasmas at atmospheric pressure are nowadays widely investigated for various environmental (flue gas and water cleaning) and bio-decontamination (sterilization) applications. [1, 2] We investigate three types of DC atmospheric discharges and test their bio-decontamination effects on selected bacteria. In sterilization, it is very important to assess the role of various effects involved. [2] We attempt to do so by employing emission spectroscopy of the investigated discharges.

Experiment

Three types of DC discharges in both polarities operating in atmospheric air with or without water in the discharge chamber were investigated: a well known streamer corona, and relatively novel transient spark (TS) and glow discharge (GD). These discharges generate non-equilibrium plasmas inducing various chemical and biological effects that play role in bio-decontamination. Each discharge generates the plasma with specific properties, so each one was studied separately [3]. Since transient spark provided the highest bio-decontamination efficiency, we only describe this regime here, as shown in Figure 1. Transient spark is a DC-driven pulsed discharge with high but very short (~100 ns) current pulses, and repetitive frequency of about 0.5-5 kHz, Due to very short pulse duration (given by a small internal capacity of the discharge chamber), the plasma cannot reach LTE conditions. On the other hand, the periodic streamer-to-spark transition provides non-equilibrium conditions with fast electrons that result in efficient chemical and biological cleaning effects. [3, 4]

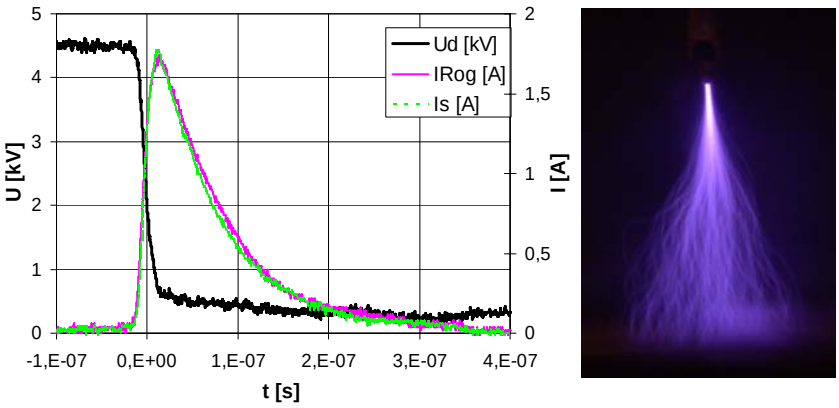


Figure 1. Transient spark typical parameters: U_d – discharge voltage, I_{Rog} - current measured by the Rogowski current monitor, I_s -measured by the current probe on a 50 Ω resistor). Photo of the discharge, gap distance 4 mm.

Biological effects of investigated DC discharges were tested on selected bacteria cultures with standard cultivation method of bacterial growth and were statistically evaluated.

1) *Salmonella typhimurium*, Gram-negative (G-) bacteria, genetically modified strain TA 98,

2) *Bacillus cereus*, Gram-positive (G+) bacteria.

S. typhi is a pathogen causing typhus diseases, and so its sterilization is important from the viewpoint of drinking water decontamination. *B. cereus* belongs to the same group as extremely hazardous *B. anthracis* (Anthrax precursor), which nowadays represents one of the highest bio-terrorism risks.

Results and discussion

The survival curves of *S. typhi* are shown in Fig. 2. The graph shows 4 experiment sets, starting at 7000 and 26 000 CFU/ml. The number of CFUs decreased with the treatment time in all discharges. We also express the relative concentration decrease, i.e. inactivation efficiency (Fig. 2, right). The highest efficiencies were obtained in the positive TS, the lowest in the coronas; GD gives fairly high efficiencies as well.

We also tested the inactivation of the G+ spore-forming *B. cereus.* It was difficult to reasonably evaluate the survival curves with these bacteria because CFUs after incubation do not form typical easily countable dots but larger stains. Nevertheless, a decrease of their concentration is demonstrated in Fig. 3: initial concentration: 12000 CFU/ml; TS (60 s): 160 CFU/ml, efficiency 98.7%.

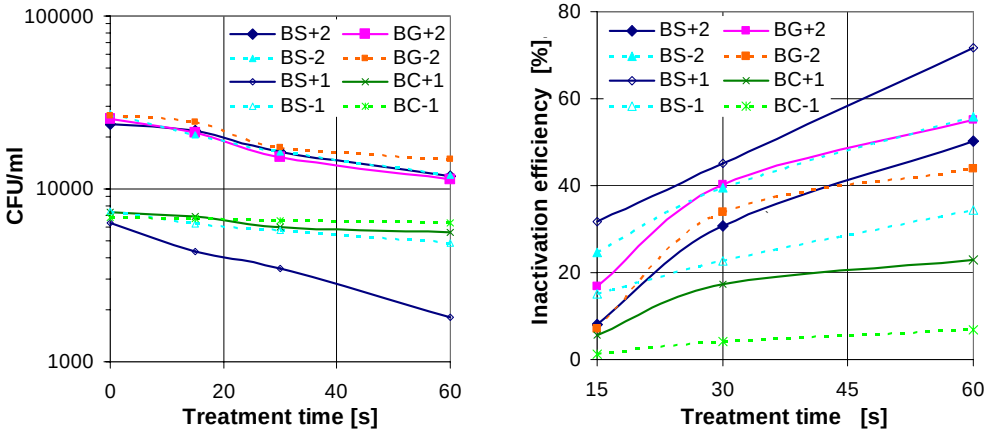
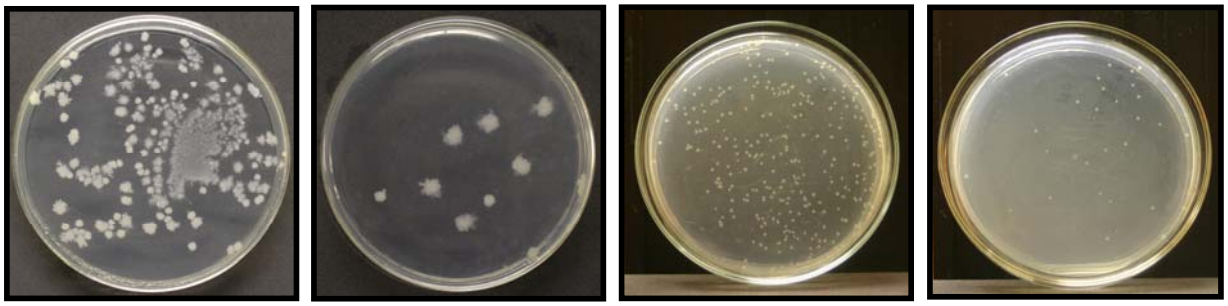


Figure 2. *S. typhi* survival curves in semi-logarithmic scale (left) and inactivation efficiency vs. treatment time (right). BS: transient spark, BG: glow discharge, BC: streamer corona, +: positive, -: negative polarity.



a *Bacillus cereus* ***b*** ***c*** *Salmonella typhimurium* ***d***

Figure 3. Cultivated bacteria on Petri dishes. Reference (a,c) and after-treatment (b,d) samples.

Conclusions

Bio-decontamination on selected bacteria (*S. typhimurium and B. cereus*) by three types of DC electrical discharges in atmospheric air with one electrode submerged in water was investigated. The discharges generate non-thermal plasmas with various gas temperatures and properties. Satisfactory results were obtained, with the highest efficiency in the transient spark. Spectroscopic discharge investigations enabled us to determine important bio-inactivation mechanisms, mainly the major role of radicals and active species.

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