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Inactivation of bacteria and cells by DC transient spark discharge

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Non-equilibrium plasma produced by positive DC-driven transient spark (TS) discharge in atmospheric pressure air [1] and its use for the inactivation of *Escherichia coli* in water solutions with various initial pH, electrical conductivities, and buffering activities; and the treatment of normal (VERO line) and tumor (HeLa line) human cells in culture media were investigated. The bactericidal effect of the discharge on *E. coli* was evaluated by plate count method and linked with chemical species and effects induced by the discharge in the treated water solutions. Changes of pH and conductivity of the solution and concentrations of hydrogen peroxide H_2O_2, nitrites NO_2^- and nitrates NO_3^-, dissolved ozone O_3, and peroxynitrites $ONOO^-$ generated by the discharge were analyzed by absorption and fluorescence spectroscopy. The cells in culture media exposed to the discharge were analyzed for viability, apoptosis and cell cycle. Direct exposure of cells to the discharge was compared with a remote exposure, where culture media exposed only to the discharge activated air flow. The results on the treatment of cells by DC transient spark in air were compared with those obtained with pulsed plasma jet in helium performed in parallel experiment. Two system setups of TS discharge were used. The first setup ('water electrode system') consisted of the high voltage needle electrode placed above the inclined plane with a narrow channel with grounded electrode. The flow rate of water in the channel was controlled by a peristaltic pump (<30 mL/min), and the discharge power (<2 W), its frequency (<4 kHz) and the treatment time (<20 min) were varied. The second setup ('water electrospray system') utilized the delivery of the water solution into the discharge zone via hypodermic stressed needle with a constant water flow rate (0.5 mL/min) and was described in detail in [2]. Finally, the plasma jet system was generated by dielectric barrier discharge at a constant gas flow rate (3 L/min) and frequency (2 kHz) and was described in detail in [3]. The results for non-buffered solutions showed that their acidity, conductivity and temperature monotonously increased with the discharge treatment time and their relative changes in both TS systems were found quite similar. Concentration of hydrogen peroxide (<1 mM), nitrites and nitrates (<1 mM), peroxynitrites (<100 μM), and dissolved ozone (~ 1 mg/L) were measured and the reduction of *E. coli* population (up to ~ 6-log) was evaluated as functions of initial pH, conductivity, buffer presence, and treatment time. Direct treatment of cells with TS systems led to the decrease in cell viability (normal cells: up to ~ 94% dead), while remote treatment indicated much weaker effect (up to ~ 10% dead, ~ 22% apoptotic, and ~ 2% preapoptotic cells). No effect of the discharge on DNA was observed. Comparison with the pulsed plasma jet results showed comparable efficiency only for remote treatment (up to ~ 10% dead).

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References

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