Physicochemical Characterization and Antimicrobial Efficacy of Plasma-Activated Water Generated by Gas-and Liquid-Phase Reactors

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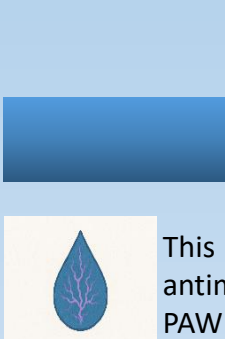
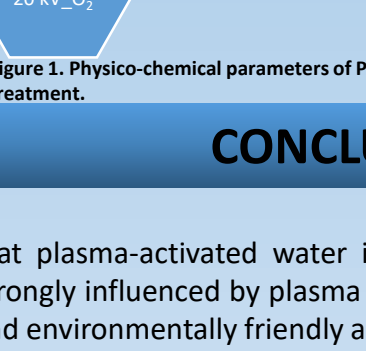
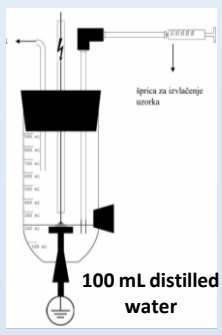
INTRODUCTION

Plasma Activated Water (PAW) is water treated with **cold plasma**, producing reactive oxygen and nitrogen species (ROS and RNS) like **H_2O_2, O_3, •OH, NO_2^-, and NO_3^-**. These reactive species give PAW strong **antimicrobial and decontamination** properties, making it effective for **sterilization and cleaning** applications.

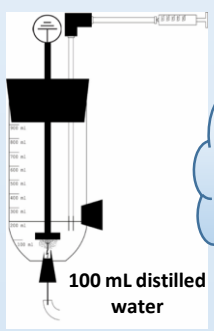




MATERIALS AND METHODS



Gas-phase plasma reactor



Liquid-phase plasma reactor

Input gasses

Ar
N_2
O_2

Treatment parameters

20 kV
30 kV
7 min

C (H_2O_2)
C (NO_3^-)
C (NO_2^-)
pH, σ, T

Salmonella enterica var. *Typhimurium*

Listeria monocytogenes

Contact time with PAW 1 h and 24 h

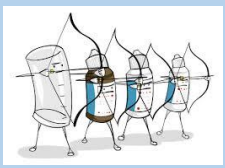
RESULTS

Table 1. Log reduction of *Listeria monocytogenes* (CFU/mL) following treatment with PAW produced in a liquid/gas reactor.

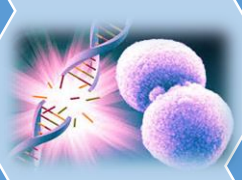
Microorganism	Sample	Δlog reduction (log CFU/mL) 3h Liquid/Gas reactor	Δlog reduction (log CFU/mL) 24h Liquid/Gas reactor
Listeria monocytogenes	T_Ar_20	0,62±0,06/2,91±0,11	5,16±0,00/3,62±0,70
	T_Ar_30	0,98±0,05/4,35±0,34	5,16±0,00/3,62±0,13
	T_N2_20	1,33±0,10/0,85±0,23	5,5±0,00/3,62±0,31
	T_N2_30	2,44±0,21/1,18±0,13	5,5±0,003,62±0,00
	T_O2_20	0,99±0,15/0,30±0,20	5,5±0,00/5,60±0,00
	T_O2_30	5,22±0,00/4,35±4,45	5,5±0,00/5,60±0,00

Table 2. Log reduction of *Salmonella enterica* (CFU/mL) following treatment with PAW produced in a liquid/gas reactor.

Microorganism	Sample	Δlog reduction (log CFU/mL) 3h Liquid/Gas reactor	Δlog reduction (log CFU/mL) 24h Liquid/Gas reactor
Salmonella enterica	T_Ar_20	1,97±0,07/4,27±0,17	6,02±0,00/3,35±0,13
	T_Ar_30	4,23±4,76/4,94±0,28	6,02±0,00/3,35±0,23
	T_N2_20	4,48±3,61/4,94±0,14	6,02±0,00/3,35±0,12
	T_N2_30	4,97±2,25/3,86±0,08	6,02±0,00/3,35±0,24
	T_O2_20	4,97±4,5/5,92±0,00	6,02±0,00/6,12±0,00
	T_O2_30	5,97±0,00/4,58±4,04	6,02±0,00/6,12±0,00



Gas-phase reactor
T – 31,1 °C
30 kV-Ar
C (H_2O_2) 21,14 mg/L 30 kV_Ar
C (NO_3^-) 25 mg/L -20 kV_N_2
σ – 85,7 µS/cm 30 kV_N_2
C ($NO2^-$) 1,84 mg/L - 20 kV_N_2
pH - 3,98 20 kV_O_2



Liquid-phase reactor
C (H_2O_2) 21,86mg/L 30 kV_O_2
T – 28,1 °C 30 kV-O_2
C (NO_3^-) 0,17 mg/L - 20 kV_N_2
σ – 96,2 µS/cm 20 kV_O_2
C ($NO2^-$) 0,20 mg/L - 20 kV_O_2
pH – 4,02 30 kV_Ar

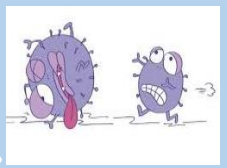


Figure 1. Physico-chemical parameters of PAW water after gas-phase and liquid phase plasma treatment.

CONCLUSIONS

This study confirms that plasma-activated water is highly effective in reducing microbial populations, with its antimicrobial activity strongly influenced by plasma parameters and working gas composition. The results highlight PAW as a sustainable and environmentally friendly alternative to traditional chemical disinfectants.

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