The Effect of Sodium Chloride (NaCl) on Reactive Oxygen and Nitrogen Species (RONS) in Plasma-Activated Water (PAW)

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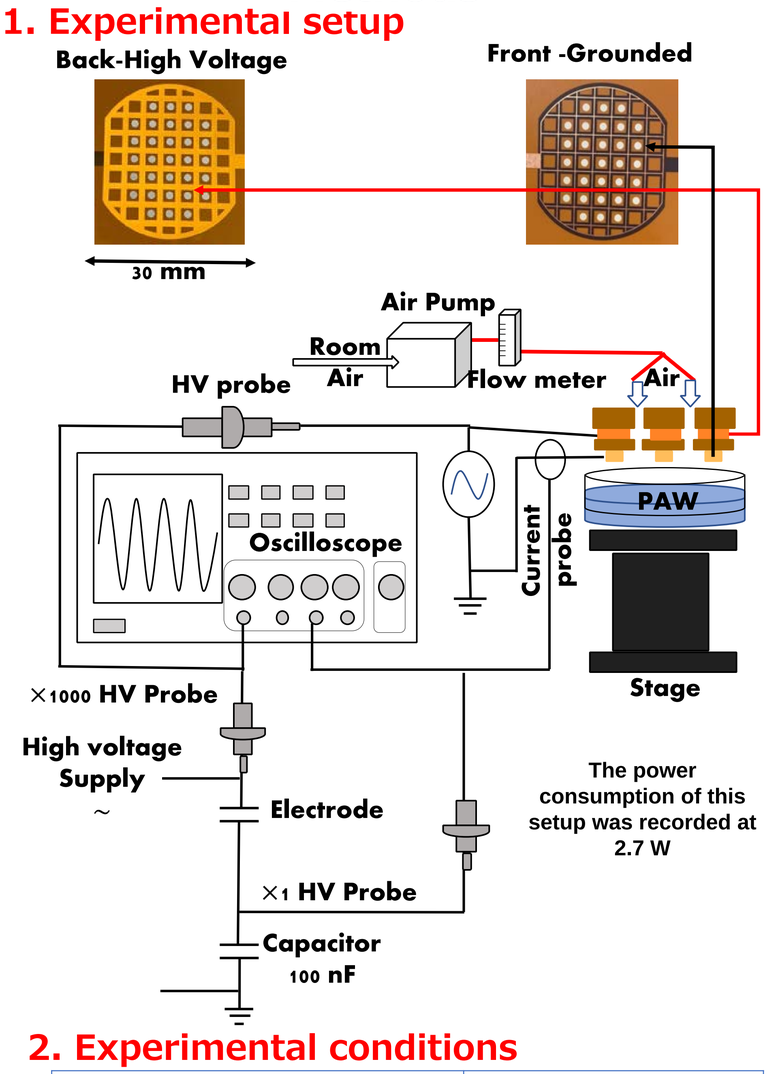
Introduction

Previous studies have shown that ordinary saline solution provides a more suitable living environment for most bacteria than deionized water. However, plasma-activated normal saline has been found to have a stronger bactericidal effect than the plasma-activated deionized water.

Dissolved H_2O_2, NO_2^- and NO_3^- play a key role in the bactericidal properties of plasma activated water (PAW). In this work, 1 - 10% sodium chloride (NaCl) PAW was generated using cold atmospheric dielectric barrier discharge (DBD) microplasma at a discharge voltage of 1.2 kV $_{(0-p)}$, AC-sine frequency of 20 kHz using a 2 L/min room air working gas. The effect of varying NaCl concentrations on NO_2^- and NO_3^- in PAW was investigated using ion chromatography (IC).

Methods

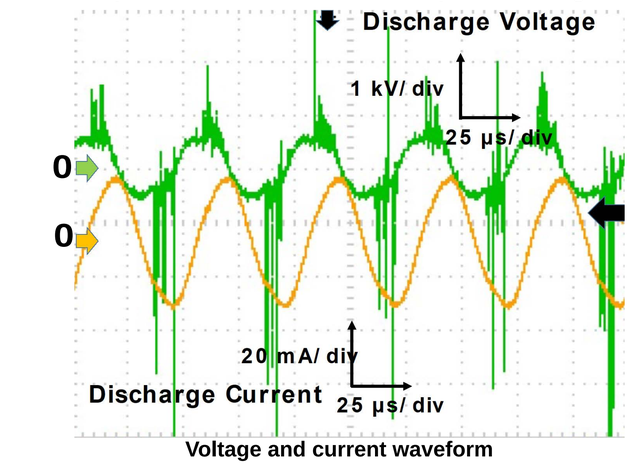
1. Experimental setup



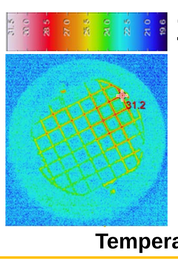
2. Experimental conditions

Discharge voltage	1.2 kV $_{(0-p)}$
SINE frequency	20 kHz
Carrier gas	Room air at
Gas flow rate	2 L/min
Treatment time	3 min
Sample volume	2 mL
Distance between electrode and samples	2 mm
Humidity	±60 %

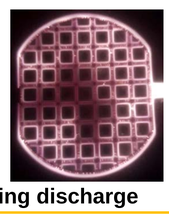
Tab.1 Experimental conditions for microplasma PAW generation



Voltage and current waveform



The temperature of the electrode was recorded by a thermal infrared camera at 31.2 ˚C



Temperature of the electrode during discharge

PAW Generation

Sodium chloride (NaCl) solutions were prepared using NaCl from (Wako, TSN1081, Japan) and fresh distilled water from a water distillation apparatus (RFD260NC, Advantec, Tokyo, Japan). 0, 1, 5 and 10% NaCl solutions were prepared by dissolving 0, 1, 5, and 10 g of NaCl per 100 mL final volume.

2 mL of these samples were treated with microplasma for 2 min. to generate PAW. The samples were diluted 2 times serially in preparation for ion chromatography analysis.

The reactive nitrogen species (NO_2^-, NO_3^-) with chloride Cl^- dissolved in the PAW were characterized by the standard solution of $NaNO_2$, KNO_3, and NaCl analysis in Fig. 2 at around 9, 12, and 18 min. respectively.

Results

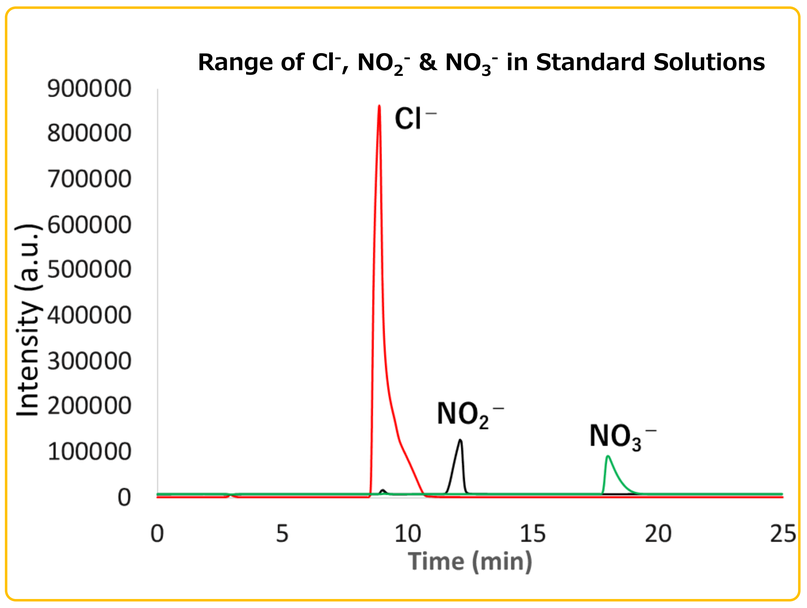


Fig. 1 Shows the chromatogram of Cl^-, NO_2^- & NO_3^- in standard solutions of NaCl, $NaNO_2$ and KNO_3 at 8, 11 and 18 min. respectively.

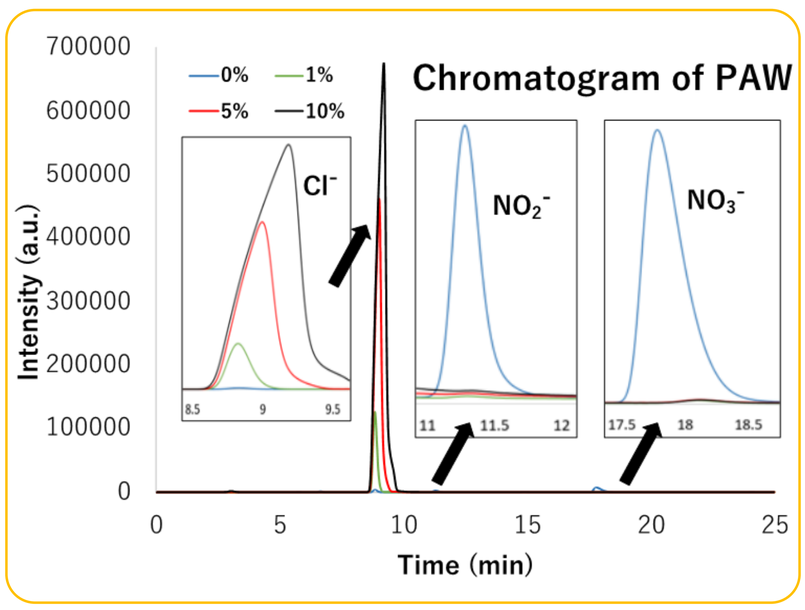


Fig. 2 Shows the chromatogram of Cl^-, NO_2^- & NO_3^- in PAW at 9, 11 and 18 min. respectivelv.

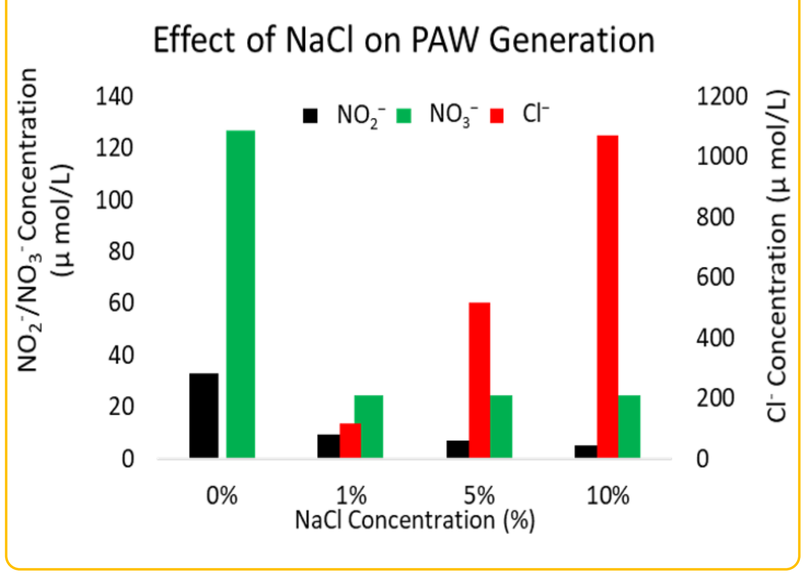


Fig. 3 Shows the concentration of NO_2^- & NO_3^- and Cl^- in PAW with increase in NaCl concentration from 0 - 10%.

Discussion

The concentration of NO_2^- and NO_3^- decreased from 32.9 to 5.2 µmol/L and 126.8 to 24.6 µmol/L respectively with increase in NaCl concentration. On the other hand, the concentration of Cl^- increased from 0 to 1070.2 µ mol/L with increase in NaCl concentration. Overall, NO_3^- was more dominant over NO_2^-. This could be due the scavenging properties of Cl^- towards hydroxyl radicals as shown below by (Jayson et al. 1973) and (Klaning et al., 1985)

$$HO^\bullet + Cl^- \leftrightarrow HOCl^{\bullet-} \quad (1)$$

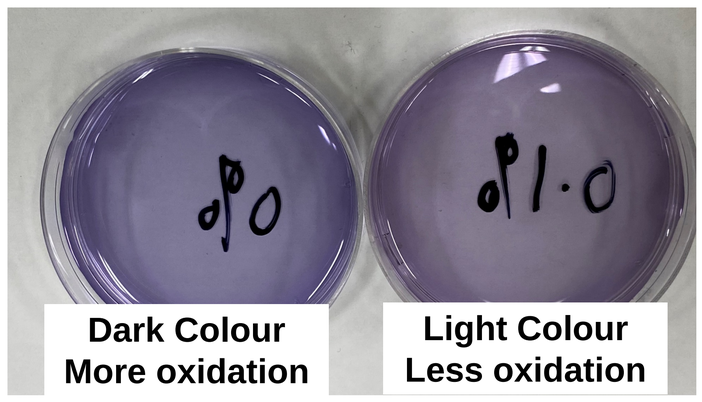
$$HOCl^{\bullet-} + H^+ \leftrightarrow Cl^\bullet + H_2O \quad (2)$$

$$Cl^\bullet + HOCl \rightarrow H^+ + Cl^- + ClO^\bullet \quad (3)$$

$$Cl^\bullet + ClO^- \rightarrow Cl^- + ClO^\bullet \quad (4)$$

$$Cl^\bullet + Cl^- \leftrightarrow Cl_2^{\bullet-} \quad (5)$$

KI Starch Experiments physically confirmed less oxidation in PAW with increase in NaCl concentration (0 – 0.1 %) in PAW as shown below.



Conclusion

- Ion chromatography was used to investigate the influence of NaCl concentration (0-10%) on NO_2^- and NO_3^- in PAW.
- It was observed that increase in NaCl concentration in PAW had a drastic effect in reducing the concentration of NO_2^- and NO_3^- from 32.9 to 5.2 µmol/L and 126.8 to 24.6 µmol/L respectively with increase in Cl^- concentration from 0 to 1070.2 µ mol/L.
- The decrease NO_2^- and NO_3^- could be attributed to the scavenging properties of Cl^- towards OH radicals.
- As a result, various chlorine-based active species including chlorine radical anions ($Cl_2^{\bullet-}$) could be formed.
- These newly formed species are less active and are not as powerful as OH radicals.
- These findings could contribute in tailoring the composition of PAW for specific use.