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Evolution of chemical composition in radical-activated water for one month

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Recently, plasma-activated water (PAW) has been paid much attention because of its huge potential for various application forms such as disinfection of medical instruments and water purification. For a decade, many researchers have reported about the mechanism of plasma sterilization in liquid phase and revealed the key species in complicated composition of reactive oxygen and nitrogen species (RONS) in the PAW. [1] The reports indicated short-living species i.e. OH• and HOO• are key species and they also assumed that electrically-neutral radicals are the generators of those species. However, there have been few reports, performing a quantitative measurement of radicals to prove that neutral radicals actually involve in the generation of bactericidal efficacy.

In this study, we employed an atmospheric-pressure radical source, which selectively supplies electrically-neutral radicals without charged species or UV photons to produce radical-activated water (RAW) and evaluated the time evolution of chemical composition using UV-Vis absorption spectroscopy.

In the experiment, deionized water (DI water) was treated with the atmospheric-pressure oxygen radical source (Fuji Machine, Tough Plasma) [2]. DI water of 700 mL was irradiated with NO radicals for 10 min. The RAW sample was dispensed into several tens glass bottles by 20 mL and stored until the investigation. We used UV-Vis absorption spectroscopy and deconvolution analysis to measure the RONS concentrations in RAW. It was found that H_2O_2, NO_2^-, NO_3^- and O_{2aq} which were generated via radical irradiation of DI water. [3] As the result, the concentrations of H_2O_2 and O_{2aq} were quite symmetric to each other as shown Fig.1. (The concentration of O_{2aq} on day 30 is a negative value, which could be explained by the initial value of O_{2aq} for the automated curve-fitting data) This result might indicate that H_2O_2 and O_{2aq} continued converting to each other by reaction (1). So far, O_{2aq} conversion to H_2O_2 has not been investigated well, so an unknown molecule which seems to involve in the O_{2aq} conversion to H_2O_2 is described as X and X'. Moreover, another strong symmetric relation was confirmed between NO_2^- and NO_3^- as shown in Fig. 2. This symmetry can be explained by reaction (2). Therefore, each H_2O_2 - O_{2aq} and NO_2^- - NO_3^- might keep converting each other and survived for 30 days since the radical treatment.

In summary, we investigated the time evolution of chemical composition in RAW. As a result, some reactive oxygen and nitrogen species such as H_2O_2 was remained even 30 days after the radical treatment.

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$$H_2O_2 + X \leftrightarrow O_{2aq} + X' \quad (1)$$

$$2H^+ + 2NO_2^- + O_{2aq} \rightarrow 2H^+ + 2NO_3^- \quad (2)$$

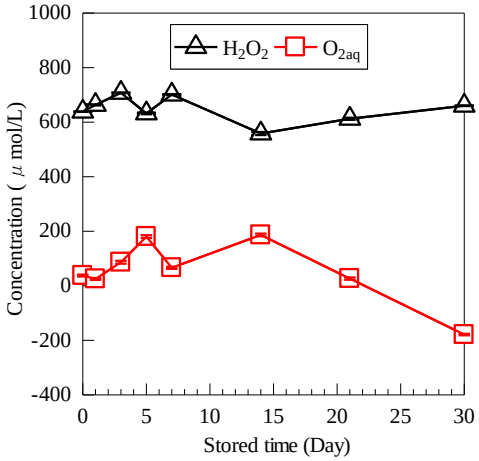

Fig. 1. Time evolution of H_2O_2 and O_{2aq} concentrations.

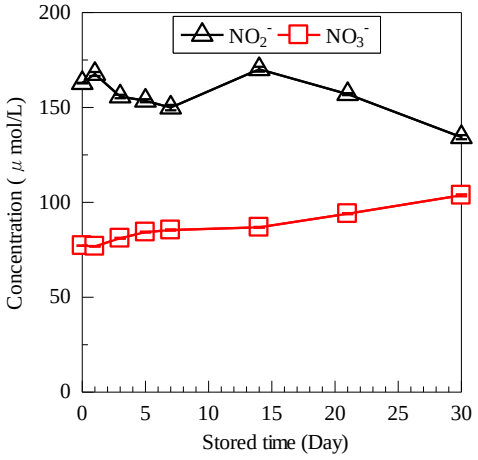

Fig. 2. Time evolution of NO_2^- and NO_3^- concentrations.

References

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