Enhancement of ozonation efficiency employing dead-end hollow fiber membranes

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Electronic Supplementary Information

Experimental setup

Fig. ESI1 Ozonation continuous flow pilot unit.

Ozone self-decomposition

1. Kinetics

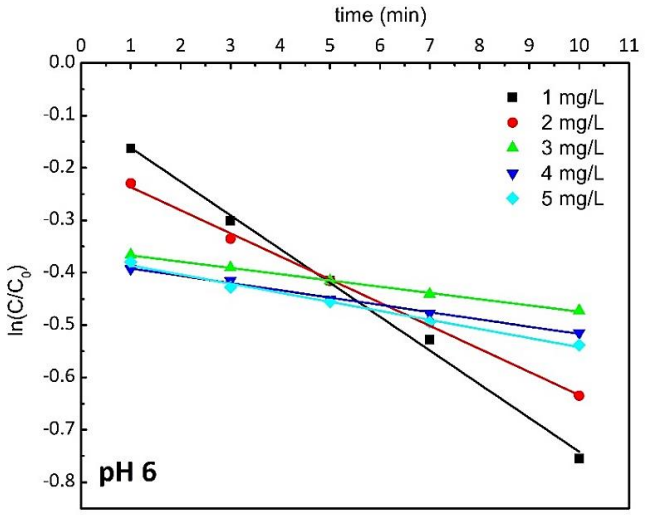

Fig. ESI2 Plot of $\ln(C/C_0)$ versus time for self-decomposition of ozone at pH 6.

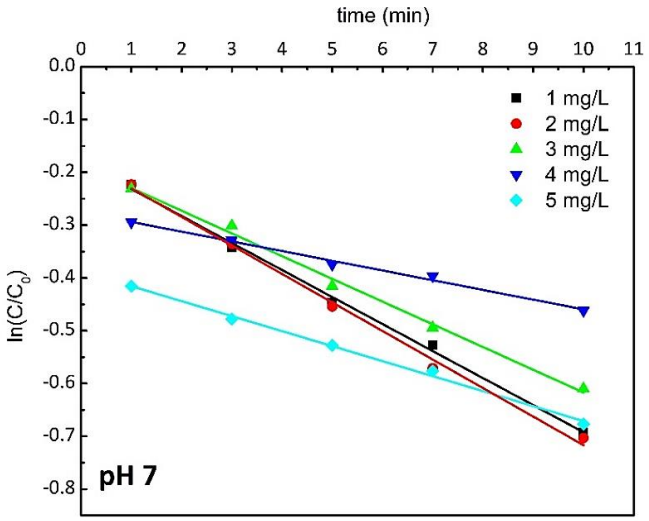

Fig. ESI3 Plot of ln(C/C$_0$) versus time for self-decomposition of ozone at pH 7.

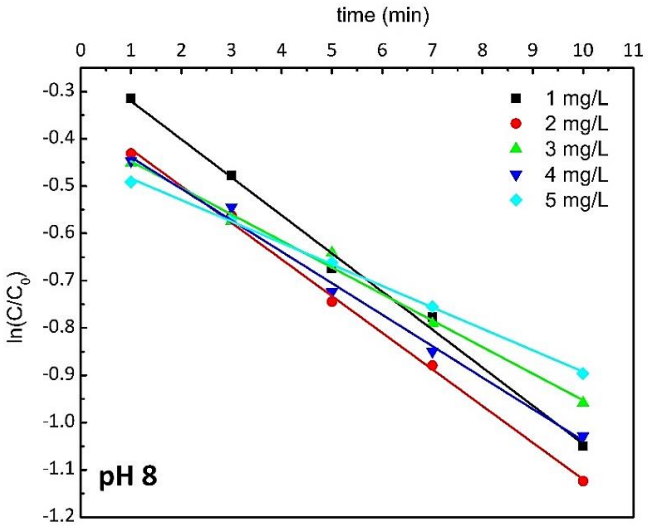

Fig. ESI4 Plot of ln(C/C$_0$) versus time for self-decomposition of ozone at pH 8.

2. Calculations for ozone self-decomposition after the membrane

The residence time for ozone self-destruction, t_d, is calculated as the sum of time intervals, Σt_i, spent in each section of the experimental set up after the mixture is exiting the membrane and just before the dissolved ozone meter. A time interval, t_i is determined as $t_i=L_i/(Q_L/E_i)$, where Q_L is the liquid flow and L_i, E_i the length and area of each section. Residence time is then corrected with volume fraction, ϕ, as $t_{d\,cor}= t_d(1-\phi)$.

Volume fraction is calculated as analytically shown below.

$$\varphi = \frac{Q_{O_2}+Q_{N_2}}{Q_{O_2}+Q_{N_2}+Q_L} \qquad \text{(ESI1)}$$

$$Q_{N_2} = \%N_2 \cdot Q_{gas} \qquad \text{(ESI2)}$$

$$Q_{O_2} = \frac{P_{STP}\cdot T}{P\cdot T_{STP}} Q_{O_2\,STP} \qquad \text{(ESI3)}$$

$$Q_{O_2\,STP} = \frac{V_{STP}}{M_{r\,O_2}} \frac{\dot{m}_{O_2}}{10^3} \qquad \text{(ESI4)}$$

$$\dot{m}_{O_2} = (C_{O_{2,Lt}} - C_{in,O_2}) Q_L \qquad \text{(ESI5)}$$

where:

Q_{gas} = volumetric flowrate of gas, L/h

Q_{O_2} = volumetric flowrate of oxygen gas ,L/h

Q_{N_2} = volumetric flowrate of nitrogen gas, L/h

$\%N_2$ = nitrogen mol fraction
P_{STP} = standard pressure (1 atm)
T_{STP} = standard temperature (273.15 K)
P = pressure (atm)
T = temperature (K)
V_{STP} = volume of a mole of gas at STP (22.4L)
$Q_{O_2\ STP}$ = volumetric flowrate of oxygen gas at STP, L/h
$M_{r\ O_2}$=molar mass of O_2
$\dot{m}_{O_2}$ = dissolved oxygen mass flow rate in the membrane, mg/L
C_{in,O_2} = dissolved oxygen concentration in the feed water, mg/L
$C_{O_{2,L}}$ = dissolved oxygen concentration in liquid outflow from the fiber, mg/L

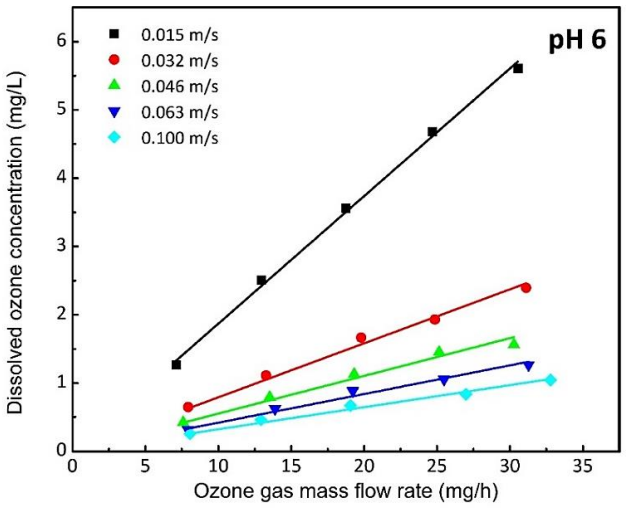

Fig. ESI5 Dissolved ozone concentrations versus ozone gas mass flow rate for different liquid velocities at pH 6 (PDMS membrane).

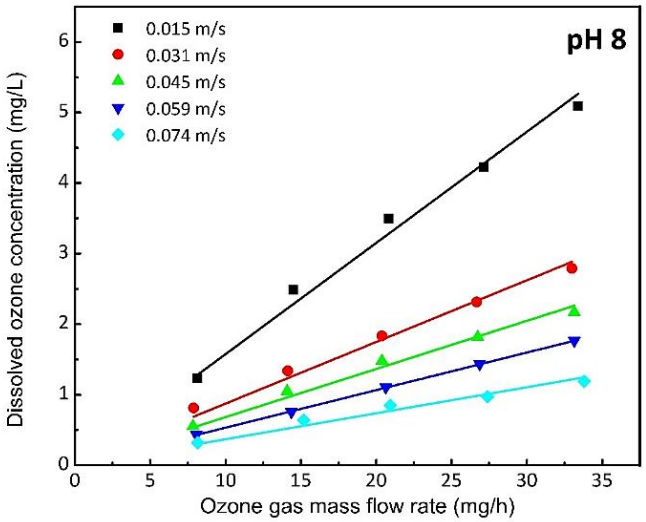

Fig. ESI6 Dissolved ozone concentrations versus ozone gas mass flow rate for different liquid velocities at pH 8 (PDMS membrane).

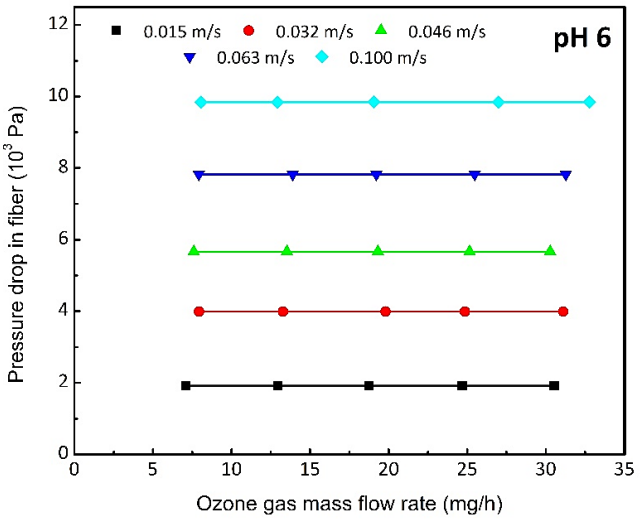

Fig. ESI7 Pressure drop in the fiber versus ozone gas mass flow rate for different liquid velocities at pH 6 (PDMS membrane).

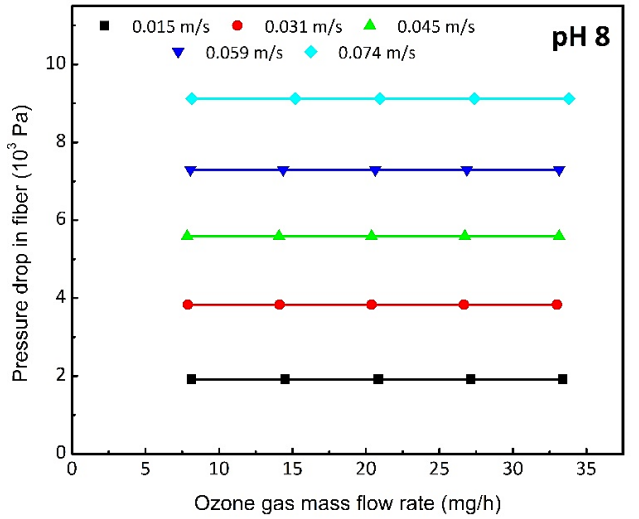

Fig. ESI8 Pressure drop in the fiber versus ozone gas mass flow rate for different liquid velocities at pH 6 (PDMS membrane).

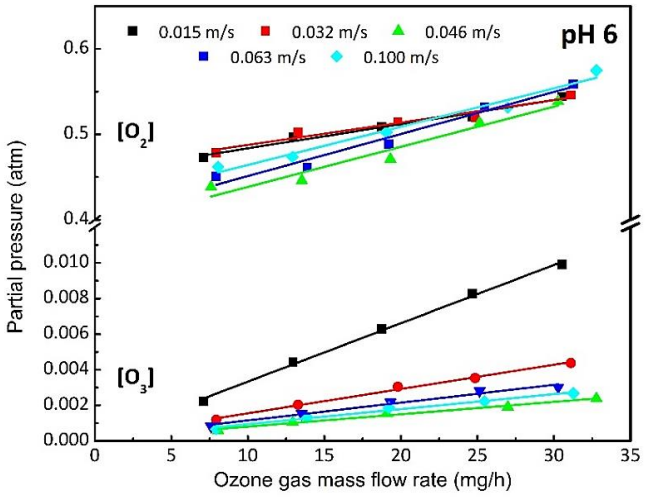

Fig. ESI9 Partial pressures of O_2 and O_3 in the shell side versus ozone gas mass flow rate for different liquid velocities at pH 6 (PDMS membrane).

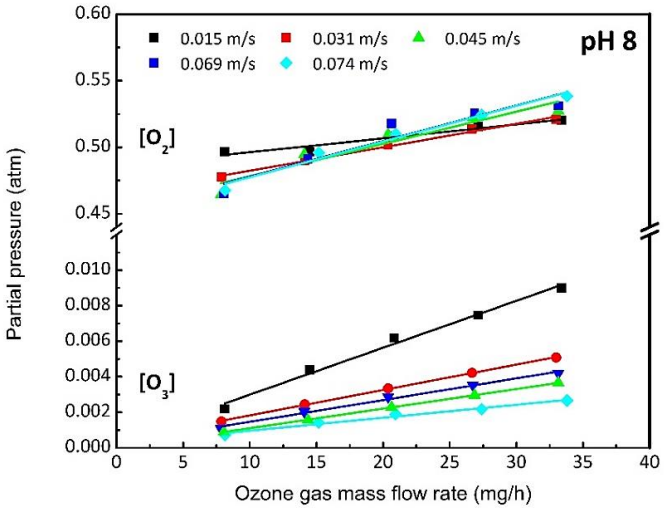

Fig. ESI10 Partial pressures of O_2 and O_3 in the shell side versus ozone gas mass flow rate for different liquid velocities at pH 8 (PDMS membrane).