Supporting Materials

Calcium carbonate scale on the GDE

Fig. S1 shows that considerable amounts of calcium carbonate precipitated on the GDE during the 46 days of electrochemical H_2O_2 production.

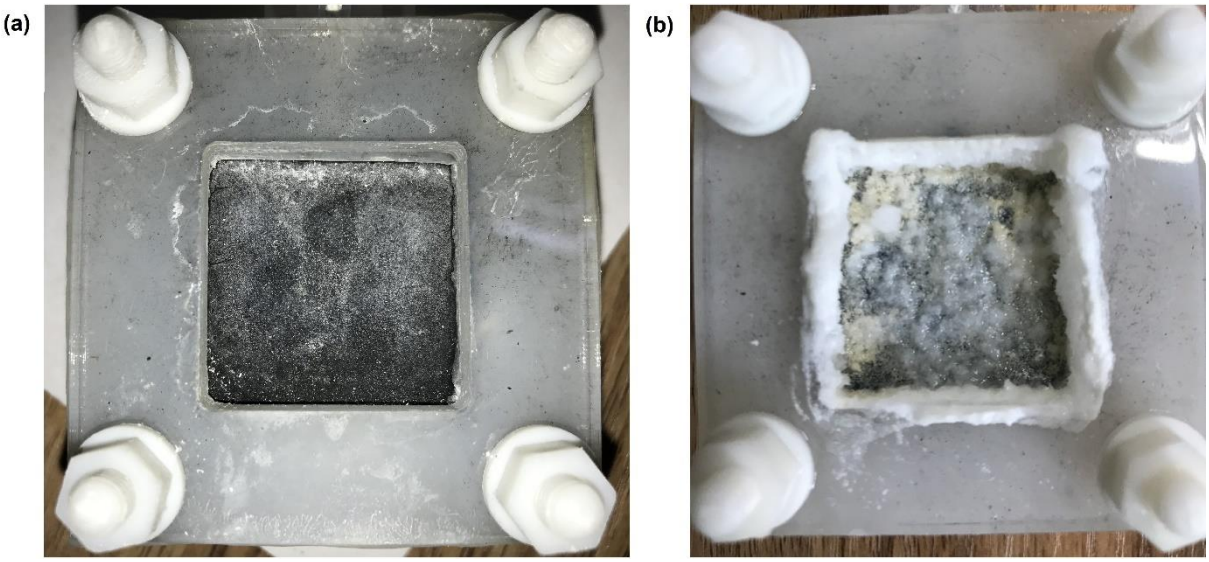

Fig. S1 Photo of calcium carbonate precipitations on the gas diffusion electrode after (a) 3 days and (b) 46 days of electrochemical H_2O_2 production

Electrode cost calculation

The market prices for Vulcan XC72 carbon black, PTFE dispersion (60 wt.%), and nickel mesh were 8.68 \$/g, 18.42 \$/kg, and 30.0 \$/m^2, respectively. Based on the amount of the raw materials used for making the CB-PTFE electrodes, the electrode cost is calculated to be ~0.0067 \$/cm^2.

Transferred and decomposed O_3 doses

During conventional ozonation and the E-peroxone treatment of the selected groundwater, the gas phase O_3 concentrations at the gas inlet and outlet of the reactor were monitored using ozone analyzers (BMT 964, Ozone Systems Technology International Inc., Germany). The transferred O_3 doses were then calculated according to the difference between ozone concentrations at the gas inlet and outlet during the treatment. In addition, the residual O_3 concentrations in the column effluent were monitored using with the indigo method (Bader and Hoigne, 1981). The decomposed O_3 doses (i.e., O_3 doses consumed in the ozone column) were then calculated from the difference between the transferred O_3 doses and residual O_3 concentrations in the effluent. Figure S2 shows that as the fed H_2O_2 doses were increased from 0 to 3.9 mg/L, transferred ozone doses increased from 3.8 to 5.2 mg/L, and decomposed ozone dosed increased from 0.8 to 5.0 mg/L. These observations indicate that the addition of H_2O_2 can considerably enhance O_3 transfer and decomposition during ozonation, in agreement with the previous findings (von Sonntag and von Gunten, 2012; Yao et al., 2018).

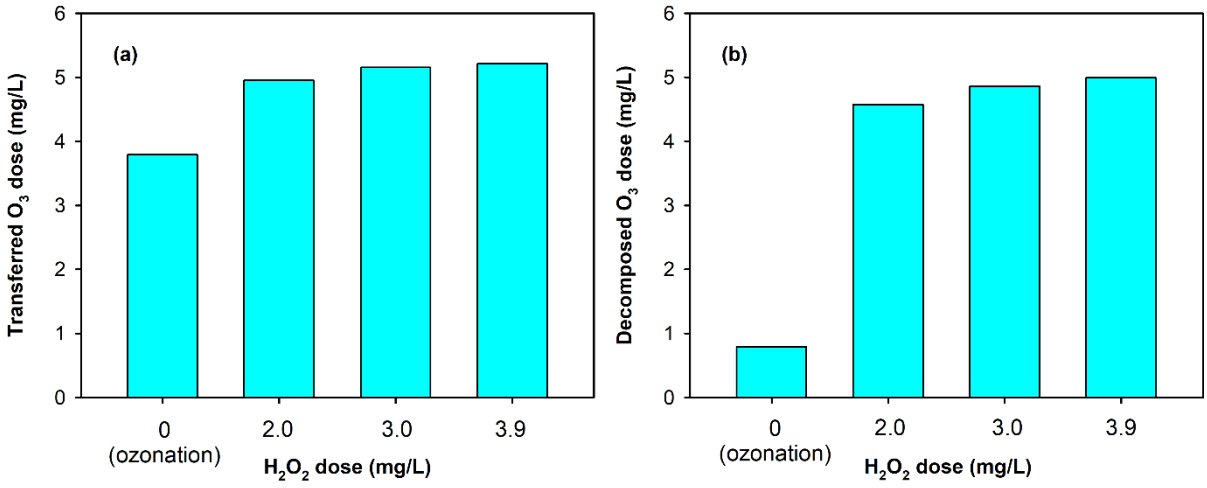

Fig. S2 (a) Transferred O_3 doses and (b) decomposed O_3 doses during conventional ozonation and the E-peroxone treatment of the selected groundwater. Operating conditions of electrochemical cell: HRT = 20 min, water flow rate = 20 mL/min, electrolyte = 0.1 mol/L Na_2SO_4, electrode area = 3 cm × 3 cm, interelectrode distance = 2 cm, current density = 40 mA/cm^2. Operating conditions of ozone column: HRT = 10 min, water flow rate = 833 mL/min, flow rate of electrochemical cell effluent = 10–20 mL/min, O_3/O_2 gas flow rate = 0.25 mL/min, gas phase O_3 concentration = 18.7 mg/L

E_{EO} calculation

Electrical energy per order (E_{EO}, i.e., the electrical energy demand to abate a pollutant concentration by 1 order in 1 m^3 of water) is a useful figure of merit for comparing the energy efficiency of different treatment systems (Bolton et al., 2001). The E_{EO} values for ibuprofen abatement in the selected groundwater by

conventional ozonation and the E-peroxone processes are calculated according to Eqs. (S1) and (S2), respectively.

$$E_{EO}(O_3)=\frac{0.06rC_{O3}Q_{O3}}{Q\log\left(\frac{C_i}{C_e}\right)}\ , \qquad (S1)$$

$$E_{EO}(EP)=\frac{0.06rC_{O3}Q_{O3}+IU}{Q\log\left(\frac{C_i}{C_e}\right)}\ , \qquad (S2)$$

where r is the energy requirement for O_3 production from oxygen (15 kWh/kg, including the production and transport of oxygen) (Hollender et al., 2009; Kovalova et al., 2013), C_{O3} is the gas phase O_3 concentration in the sparged O_2/O_3 gas (mg/L), Q_{O3} is the flow rate of sparged O_2/O_3 gas (L/min), Q is the flow rate of the water (L/h), C_i the initial concentration of a specific micropollutant (μg/L), and C_e is the effluent concentration of a specific micropollutant (g/L), I is the applied current (A), U is the average cell voltage (V). Note that Eqs. (S1) and (S2) implicitly assume first-order kinetics for micropollutant abatement (Bolton et al., 2001). For micropollutants whose abatement efficiency was below 90% during the treatments, E_{EO} values is based on extrapolation (Pisarenko et al., 2012).

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