Thank you to our Patrons
Locally Enhanced Electric Field Treatment (LEEFT) for Disinfection

Xing Xie

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Acknowledgements

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  - etc.

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Bacteria Inactivation

- Seeking for efficient bacteria inactivation methods is important.

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Locally Enhanced Electric Field Treatment (LEEFT)

- Environmental Science Technology, 2016, 50: 7641-7649
- Environmental Science: Water Research & Technology, 2018, 4, 872-881
- Scientific Reports, 2018, 8, 15832
- Journal of Materials Chemistry A, 2018, 6, 18813-18820
- Advanced Energy Materials, 2019, 1901320
- Chemical Engineering Journal, 2019, 369, 1005-1013
- Journal of Materials Chemistry A, 2019, 7, 7347-7354
- Environment International, 2019, 128: 30-36
- Environment International, 2019, 132: 105040
- Environmental Science: Nano, 2020, 7: 397-403
- Environmental Science: Nano, 2020, 7: 2021-2031
- Environmental Science Technology, 2020, 54: 14017-14025
- Frontier of Environmental Science & Engineering, 2020, 14: 78
- Journal of Materials Chemistry A, 2020, 8, 12262-12277
- Water Research, 2021, 207: 117817
- Nano Letters, 2022, 2: 860-867
Electric Field Treatment (EFT)

$\Delta V$: several kV

$E_{\text{ext}}$

Pore in membrane
Locally Enhanced Electric Field Treatment (LEEFT)

Macro-scale enhancement

Micro-scale enhancement

- Combine Macro- & Micro-scale enhancement
- **Tubular coaxial-electrode** configuration
  - Two levels of electric field enhancement

Electrode fabrication

– PDA-CuONW-Cu

Tubular Coaxial-electrode LEEFT

- Electrode morphology

- Water disinfection performance \((E. \ coli)\)
  - 99.9999\% inactivation with 1 V

Tubular Coaxial-electrode LEEFT

- Effective against *multiple strains of bacteria*

- Highly *scalable* (180 cm)

Tubular Coaxial-electrode LEEFT

- Potential application in pipelines

Water treatment plant (Primary disinfection)

Water distribution system (Secondary disinfection)

Users

LEEFT device

1 V

**Mechanism**

I: LEEFT could **enhance** the **permeability** of the cell membrane, so to **promote** the **diffusion** of O$_3$ into the cells to oxidize **intracellular** substances.

→ LEEFT makes O$_3$ more efficient.

II: O$_3$ could **inhibit** the **resealing** of pores induced by **reversible electroporation** during LEEFT.

→ O$_3$ makes LEEFT more efficient.

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Mechanism
TriboPump: A Low-cost Hand-Powered Water Disinfection System

Ding et al. @ Georgia Tech

LEEFT-Cu Powered by Cell-Phones

App

OTG hardware

Integrated system

J. Zhou et al. npj Clean water. 2020, 3 (1), 1-9
LEEFT Electrodes

Visualization of LEEFT

- Treat with Poly-L-lysine;
- Immobilize Staphylococcus;

- Stain with live/dead cell stain PI

Apply pulses Operando investigation

Load onto a microscope

Visualization of LEEFT

• Cell membrane damage occurs at the nanowedge tip, where the nano-enhanced electric field has the highest strength.
Visualization of LEEFT

LEEFT: 18 V/2 μs pulse width/100 μs period

- Free-moving cells are attracted to nanowedge tips on both electrodes and then get inactivated.
- Combination of both electrophoretic force and dielectrophoretic force.

Antimicrobial efficiency:
- 2000 ns pulses → 20 ns pulses
  - CEFT: drops dramatically.
  - LEEFT: decreases slightly.

20 ns pulses: LEEFT shows a significant advantage
- EF is reduced by 8 times;
- Pulse number is reduced by $10^6$ times.
Operando Mechanism Study of LEEFT

- Reversible electroporation is quick pore closure after the electric field is removed – a unique property of electroporation.
- Quick pore closure under 20 ns pulses at 12 kV/cm.

The ultrafast bacteria inactivation is induced by electroporation.

The nanowedges not connected to the electrodes but between two electrodes: achieve EF enhancement and induce ultrafast bacteria inactivation.

Densely packed smaller nanowires: a potential antimicrobial surface.
Applications of LEEFT

- A transformative water disinfection method
  - High microbial inactivation efficiency
  - Broad-spectrum effective to all pathogens
  - Fast treatment process
  - Low capital, operational, and maintenance cost
  - No impact on the physical and chemical property of the treated water (i.e., neither generating DBPs nor releasing toxic metals nor increasing the corrosivity)
  - Operate on electricity without any chemical consumption
  - No overtreatment concerns
  - No secondary pollution in terms of odor, sound, or light
  - Easy to operate and possible for automatic operation
  - Completely safe to operators and nearby community
Applications of LEEFT

- Other applications
  - Liquid food pasteurization
  - Algae-bloom control
  - Air disinfection
  - Anti-microbial surface
Disinfection is important

We still need better technologies for disinfection

Locally enhanced electric field treatment (LEEFT) is a promising candidate for next-generation disinfection
Thank you!

Xing Xie

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