



BILL & MELINDA
GATES foundation



A large, semi-transparent black rectangular box covers the central portion of the slide. Inside this box, the following text is displayed in white:

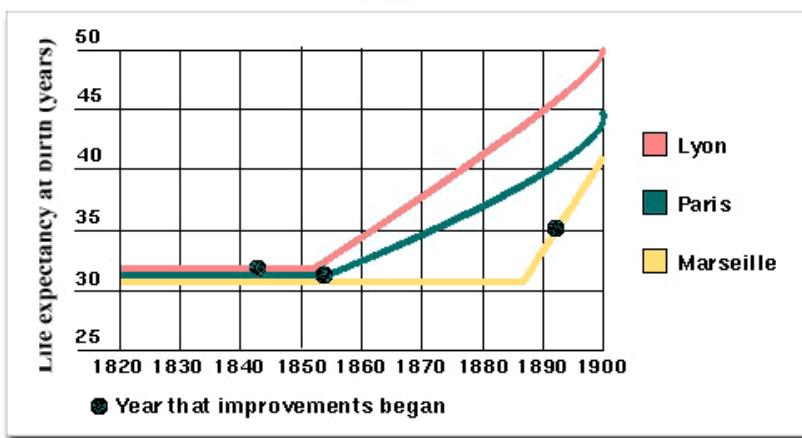
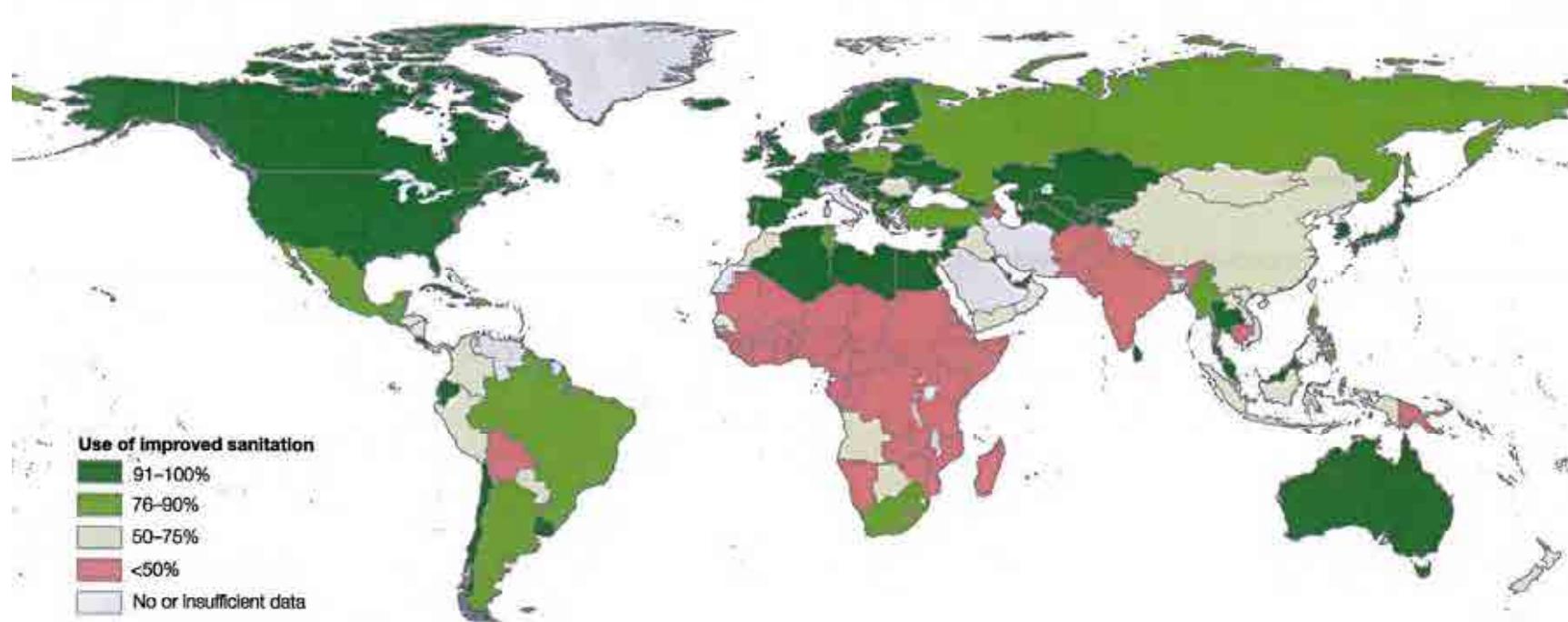
2.6 billion people live without access to safe toilets! – Would electrochemistry be an answer to the Sanitation Crisis?

Urban Sanitation Challenges in the Developing
World, Bangalore 11/05 – 11/06 2014

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Environmental Science and Engineering
California Institute of Technology

Use of improved sanitation in the world



Source: WHO/UNICEF (2010)

Source: The World Bank Group

Pathogens in Untreated Municipal Wastewater and Excreta (NRC, 1998)

Agent	Disease
Virus <i>Adenovirus</i> <i>Poliiovirus</i> <i>Hepatitis A virus</i>	20 - 400 nm <i>Respiratory disease, eye infections</i> <i>Paralysis, aseptic meningitis</i> <i>Infectious hepatitis</i>
Bacteria <i>Campylobacter jejuni</i> <i>E. coli 0157:H7</i> <i>Salmonella</i>	0.5 - 5 μm <i>Gastroenteritis, long term sequelae (e.g. arthritis)</i> <i>Bloody diarrhoea, hemolytic uremic syndrome</i> <i>Salmonellosis, long term sequelae (e.g. arthritis)</i>
Protozoa <i>Cryptosporidium parvum</i> <i>Cyclospora cayetanensis</i> <i>Entamoeba histolytica</i>	> 5 μm <i>Cryptosporidiosis, diarrhoea, fever</i> <i>Persistent diarrhoea</i> <i>Amebiasis (amebic dysentery)</i>
Helminths <i>Ascaris (roundworm)</i> <i>Ancylostoma (hookworm)</i> <i>Clonorchis (liver fluke)</i>	20 - 80 μm, eggs <i>Ascariasis</i> <i>Hookworm</i> <i>Clonorchiasis</i>

Improved sanitation?

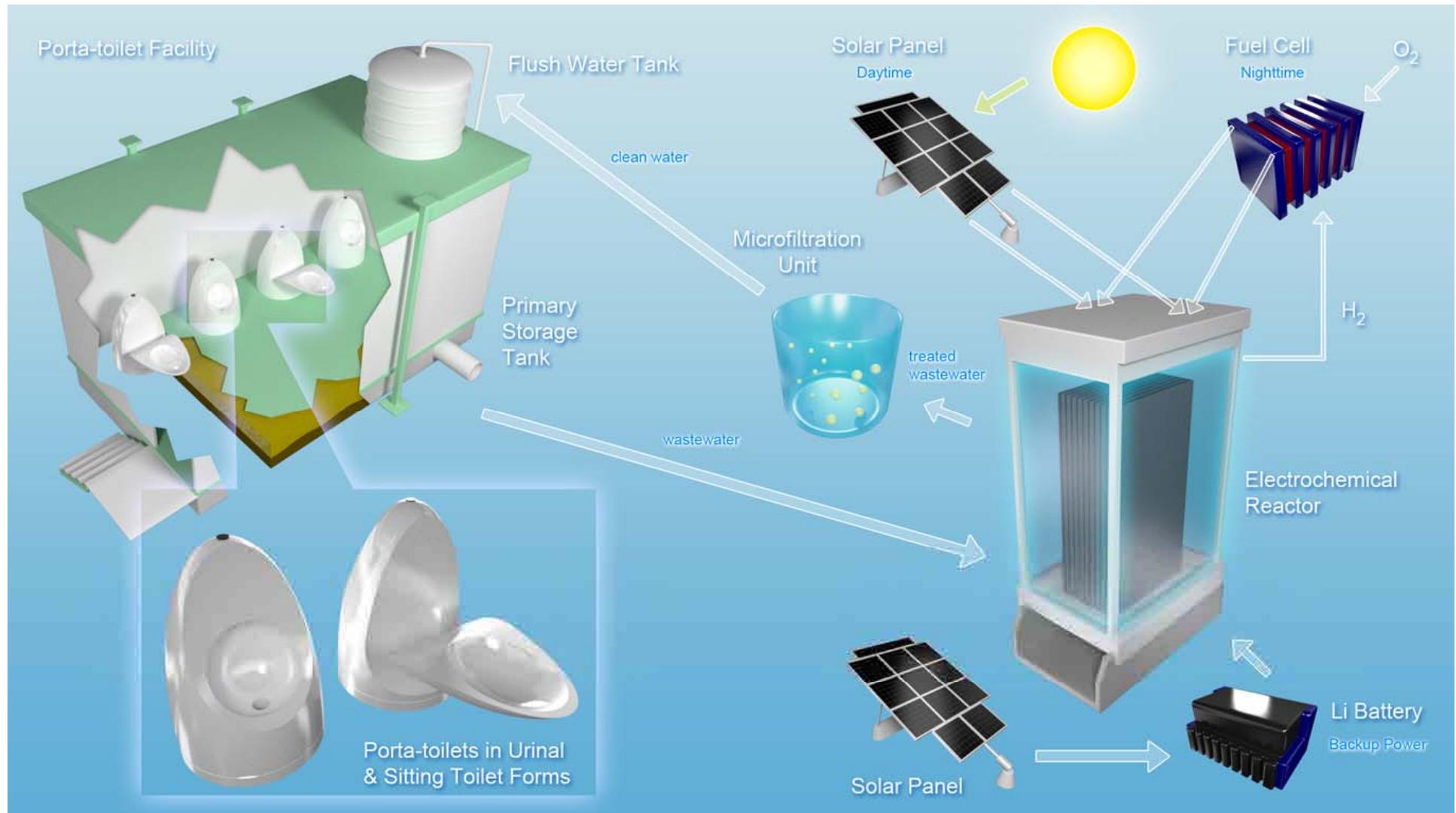


Left: Ventilated pit-latrine (VIP), Durban region, South Africa

Center: Compost toilet, <http://www.thequirkymomma.com>

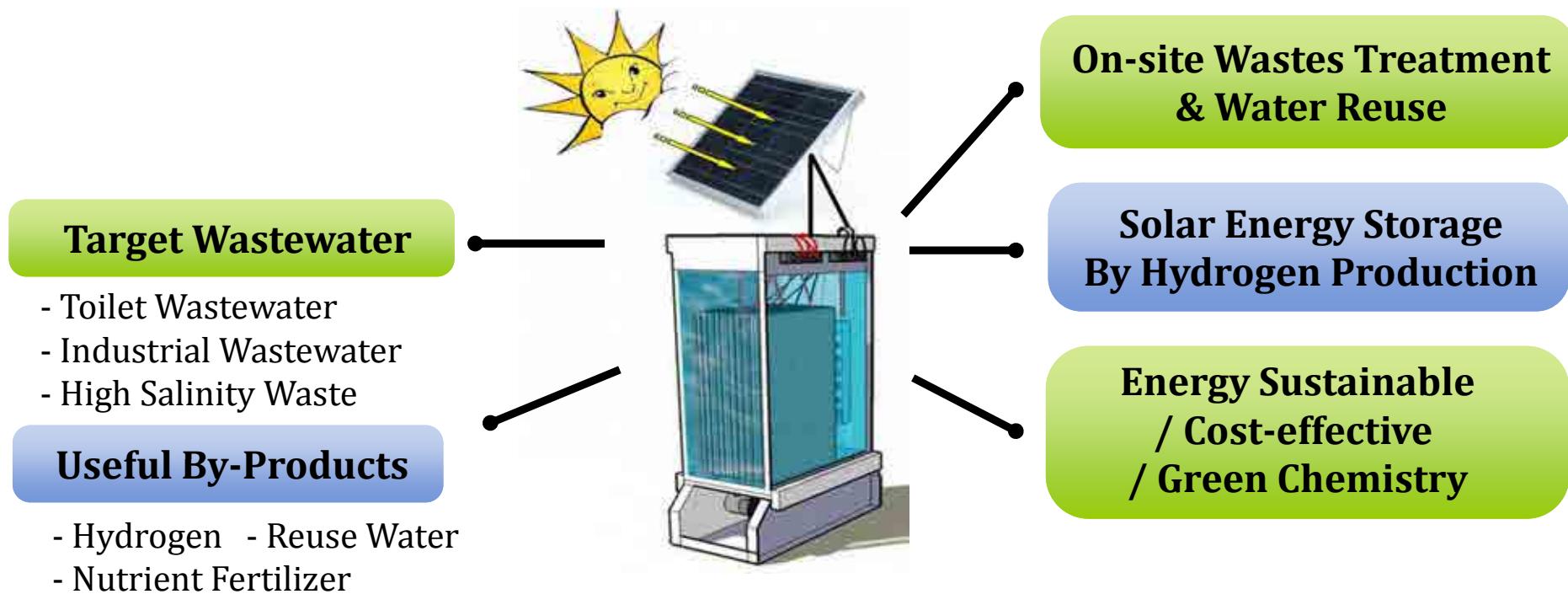
Right: Flush toilet, Belize City, 1975.

An Integrated Solar Fuels System

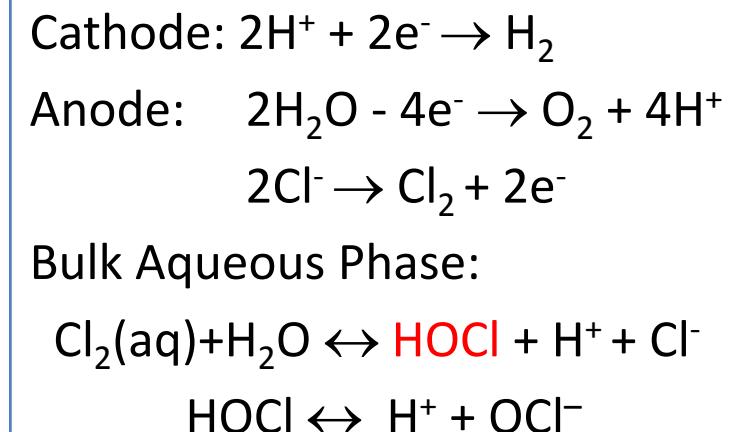
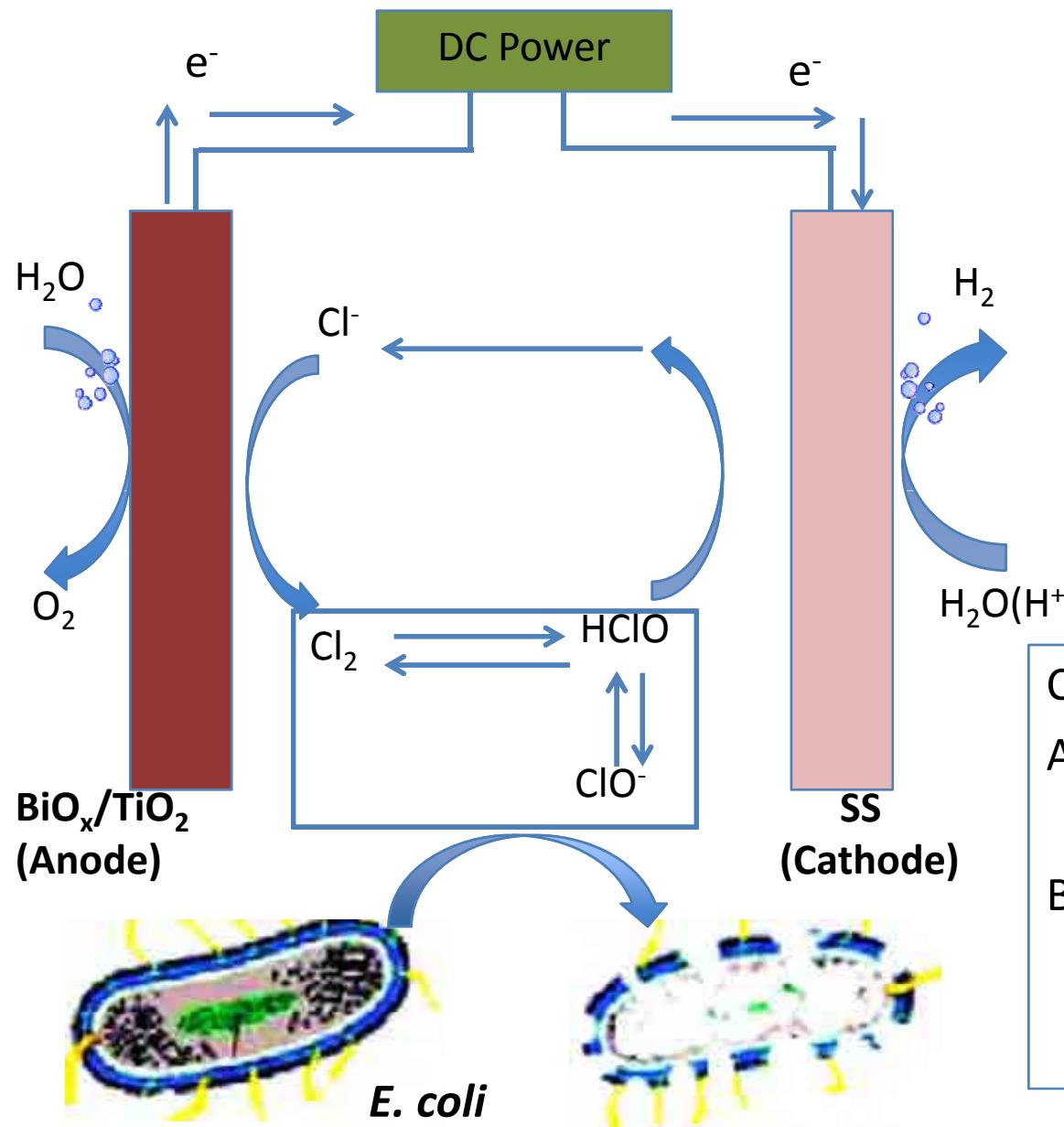


Caltech RTTC Project: Development of a Self-Contained, PV-Powered Domestic Toilet and Wastewater Treatment System

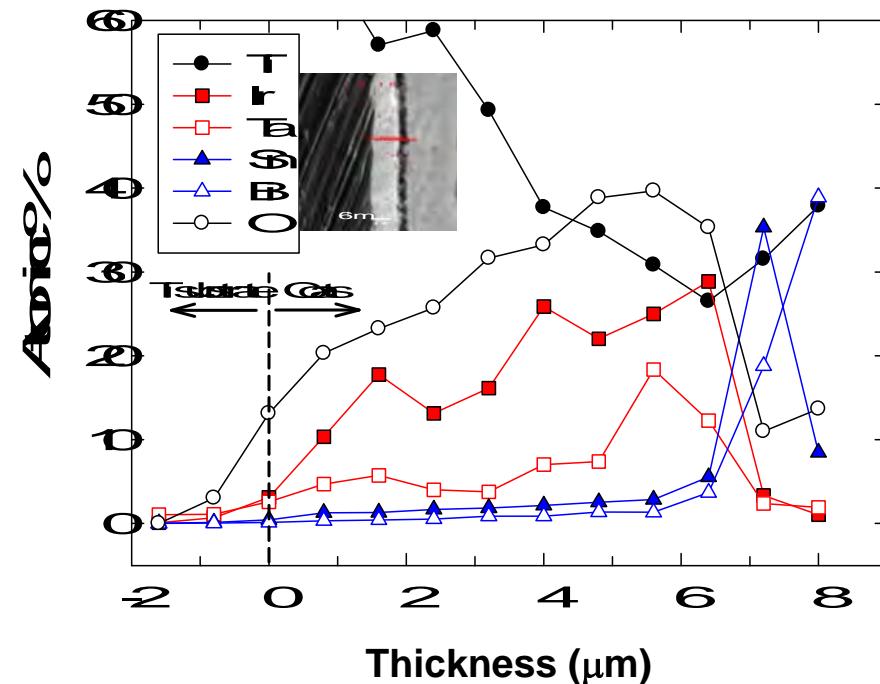
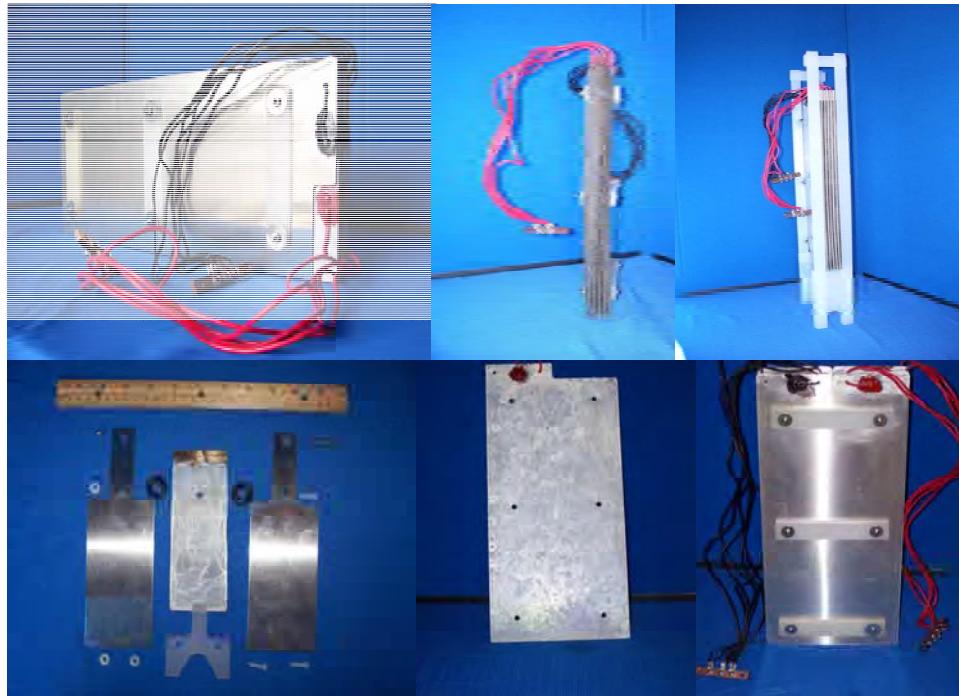
How?



Electrochemical Disinfection



$\text{IrO}_2/\text{Ta}_2\text{O}_5/\text{SnO}_2/\text{Bi}_2\text{O}_3/\text{TiO}_2$ Composite Anodes

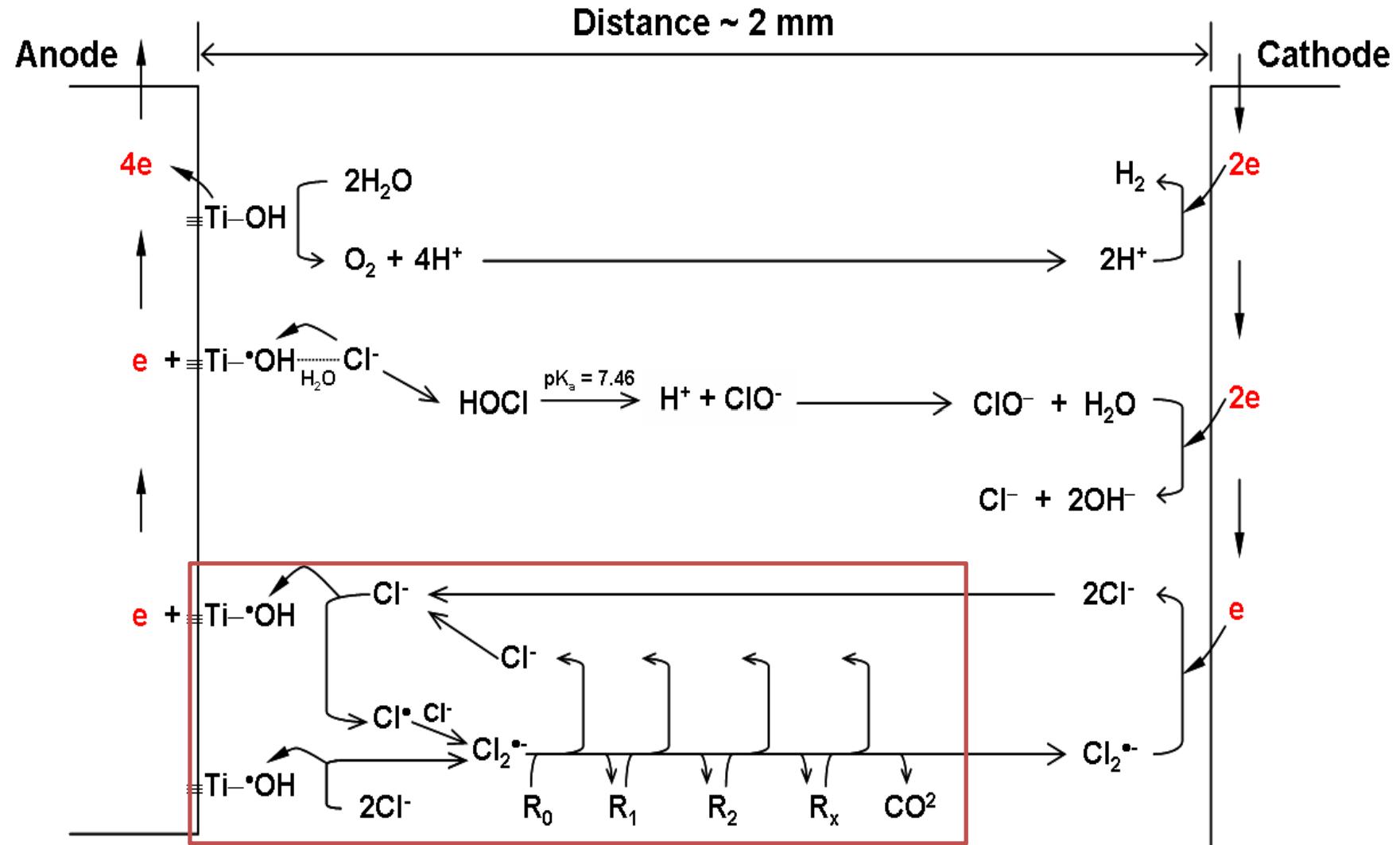


Over-coat ($\text{TiO}_2/\text{Bi}_2\text{O}_3$)	$\text{TiO}_2/\text{Bi}_2\text{O}_3$ (Ti:Bi = 90:10 by mol%), 2×(OC, ad, 5@250, H ₂ O, 5@250) 2×(OC, ad, 5@425, H ₂ O, 5@425)
Slurry coat	Bi-doped TiO_2 (Ti:Bi = 96:4 by mol%), 7×(slurry, OC, ad, 5@250)
Seal coat	$\text{SnO}_2/\text{Bi}_2\text{O}_3$ (Sn:Bi = 90:10 by mol%), 2×(2×(SC), 10min@425)
Precoat (Anti-passivation layer)	$\text{IrO}_2/\text{Ta}_2\text{O}_5$ (Ir:Ta = 67:33 by mol%), 1×(1 hr@525), 5×(10 min@525)
Substrate	Ti-Gr.2 sheet 0.020 inch thick, 2.25×5.75 inches

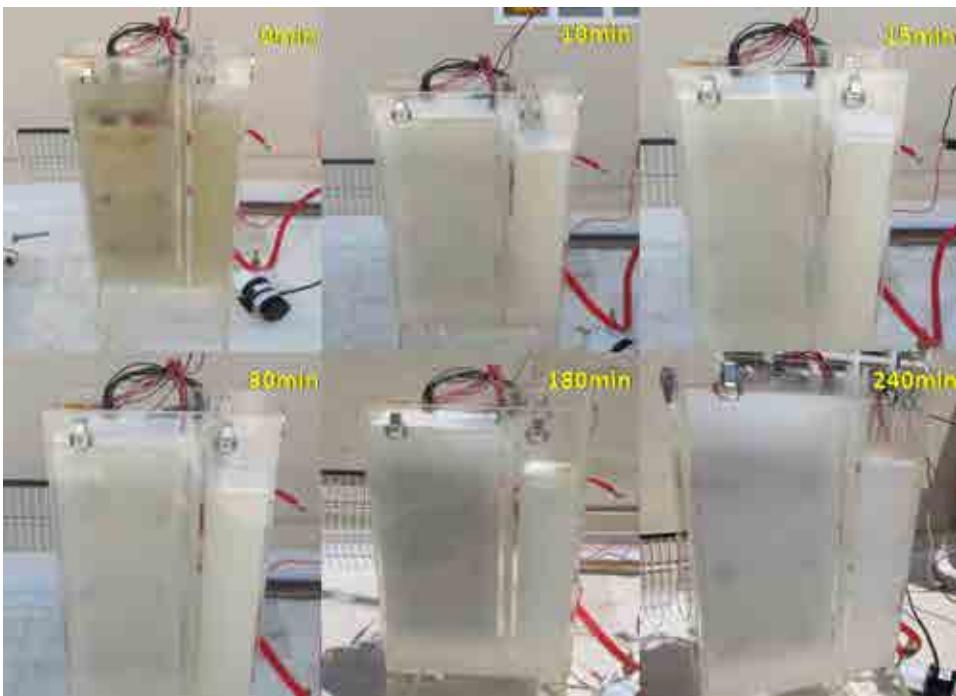


From Park *et al.*, *J. Phys. Chem. A*, **2008**, *112* (33), pp 7616–7626

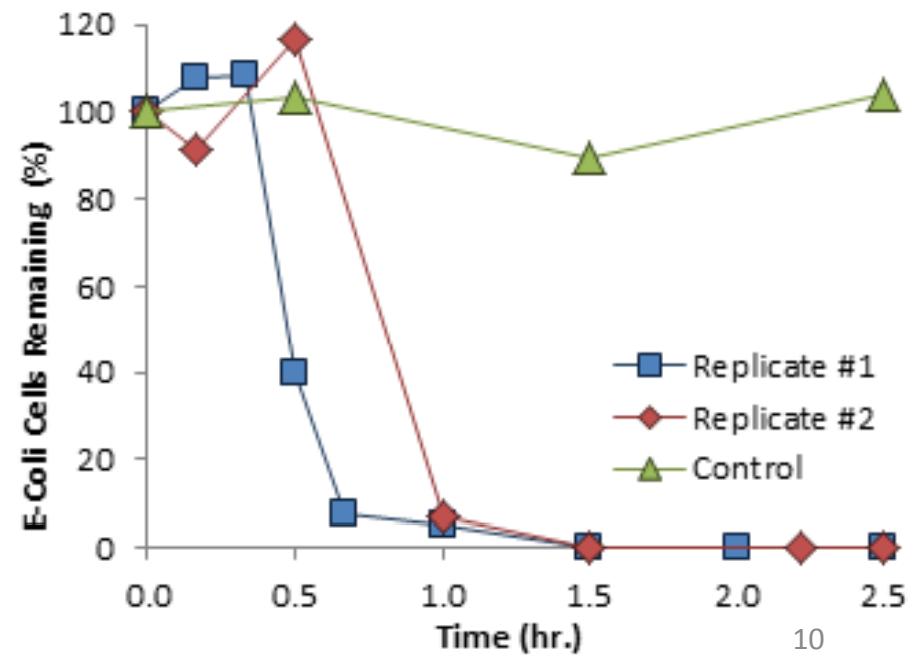
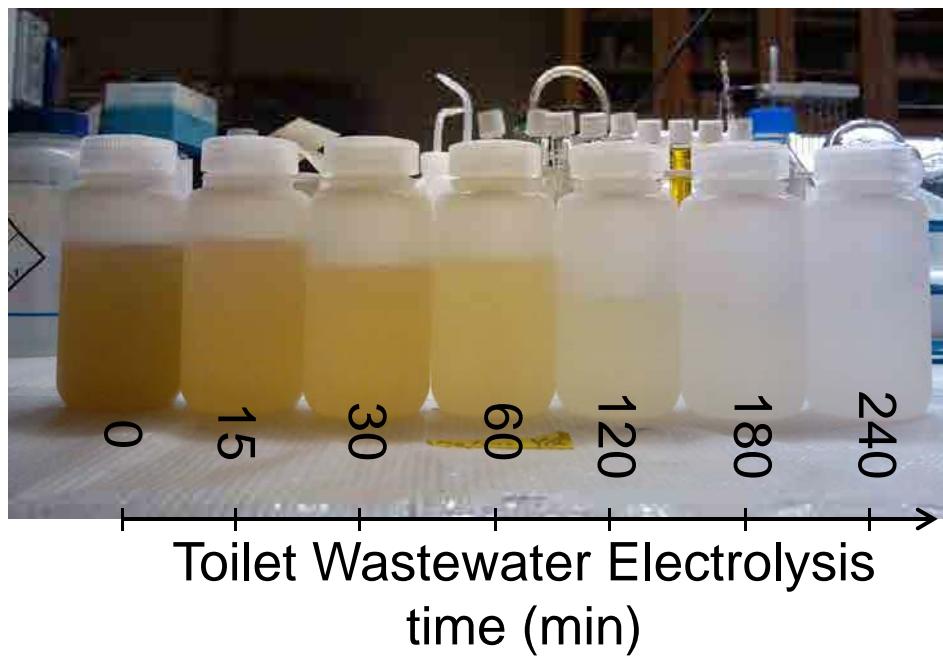
$\text{IrO}_2/\text{Ta}_2\text{O}_5/\text{SnO}_2/\text{Bi}_2\text{O}_3/\text{TiO}_2$ Composite Anodes



$$\begin{aligned}
 E(\text{HClO}, \text{H}^+/\text{H}_2\text{O}, \text{Cl}^\bullet) &= -0.46 \text{ V}; \\
 E(\text{HOCl}/\text{Cl}^\bullet, \text{OH}^-) &= -0.04 \text{ V}; \\
 E(\text{ClO}^\bullet/\text{Cl}^\bullet, \text{HO}^-) &= 1.90 \text{ V} \\
 E(\text{Cl}^\bullet/\text{Cl}^-) &= 2.55 \text{ V}; \\
 E(\text{Cl}_2^\bullet/2\text{Cl}^-) &= 2.3 \text{ V}; \\
 \text{Cl}^\bullet + \text{Cl}^- \leftrightarrow \text{Cl}_2^\bullet \quad K &= 1.4 \times 10^5 \text{ M}^{-1}
 \end{aligned}$$



Time-lapse Video of Reaction Progress



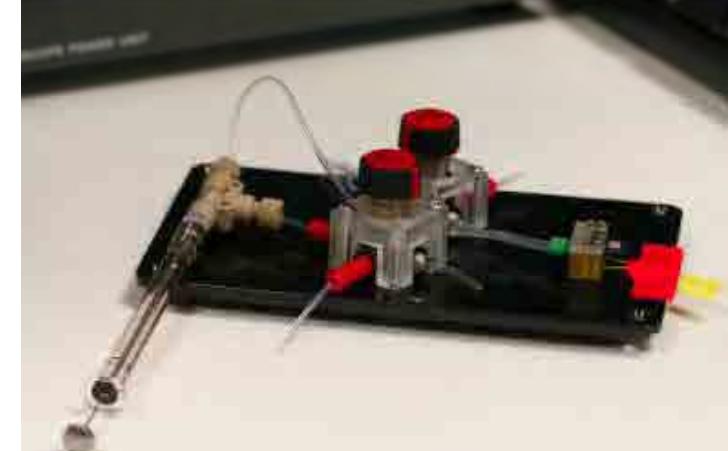
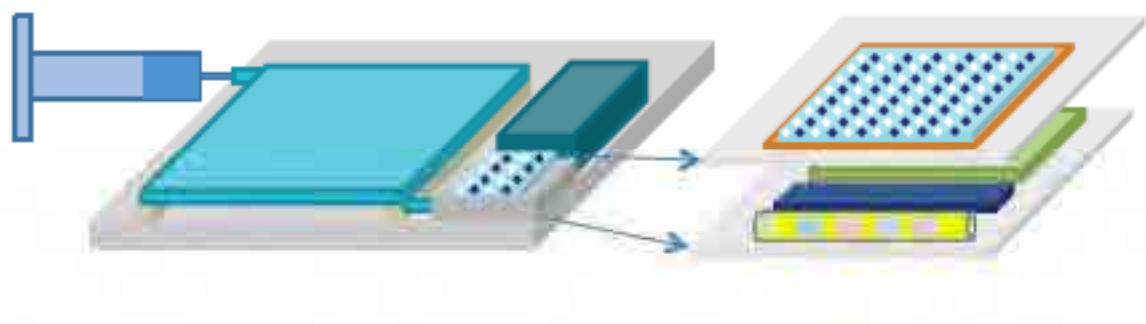
Fecal Coliform Counts vs. Time

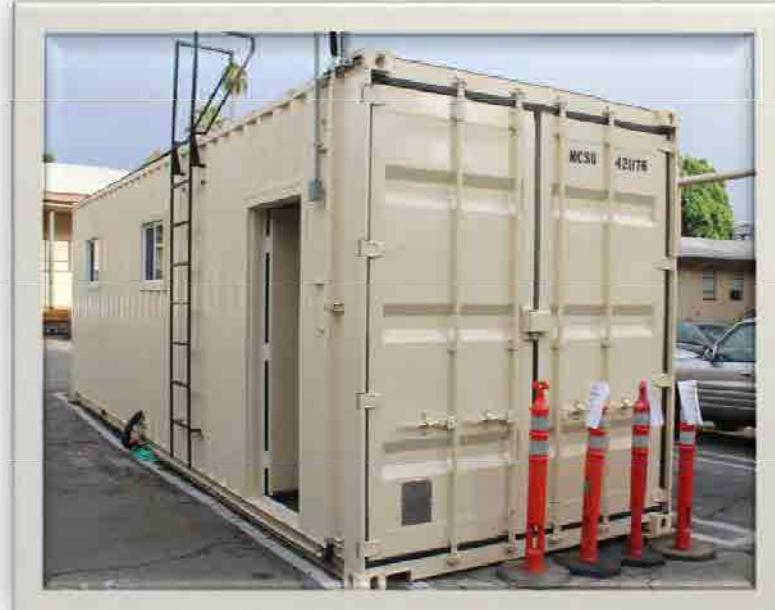
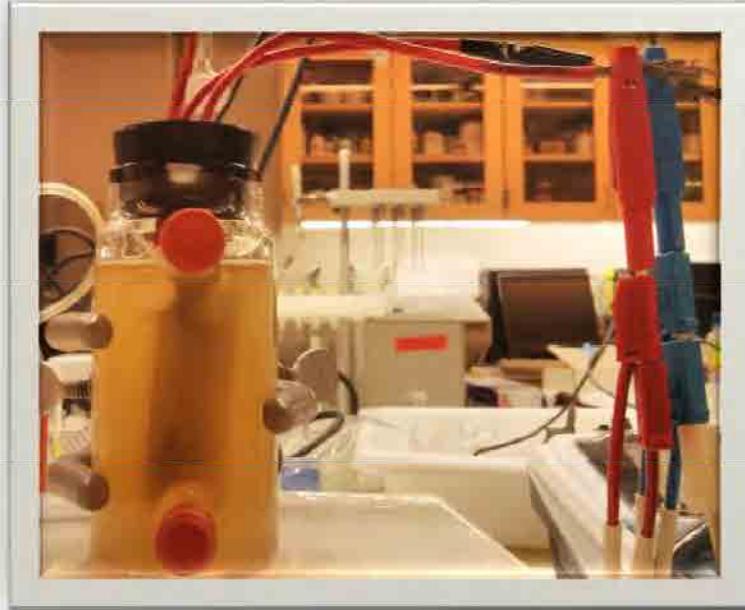
0.01 mL, t = 0 min 0.1 mL, t = 15 min 0.1 mL, t = 30 min 0.1 mL, t = 60 min

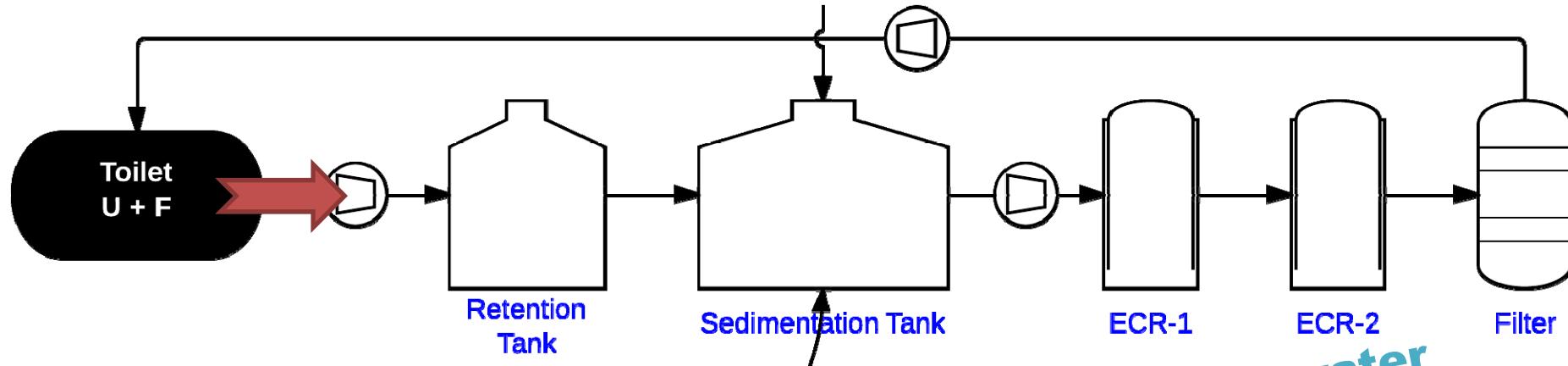


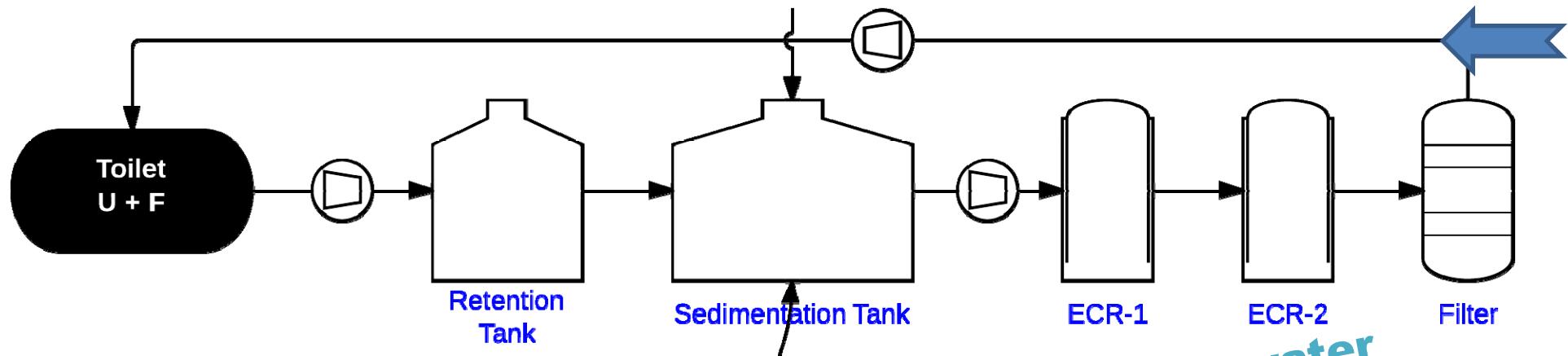
Electrochemical Disinfection: Total Coliforms vs. Time

0.01 mL, t = 0 min 0.1 mL, t = 30 min 0.1 mL, t = 60 min 0.1 mL, t = 100 min

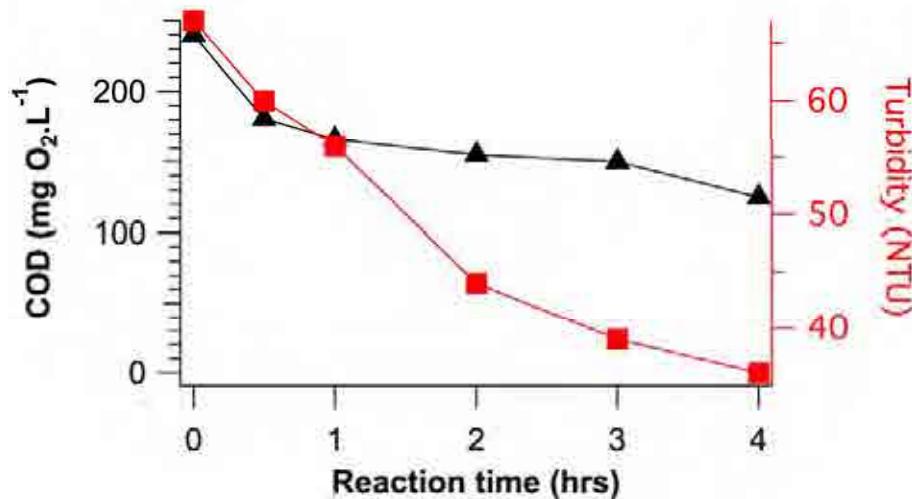
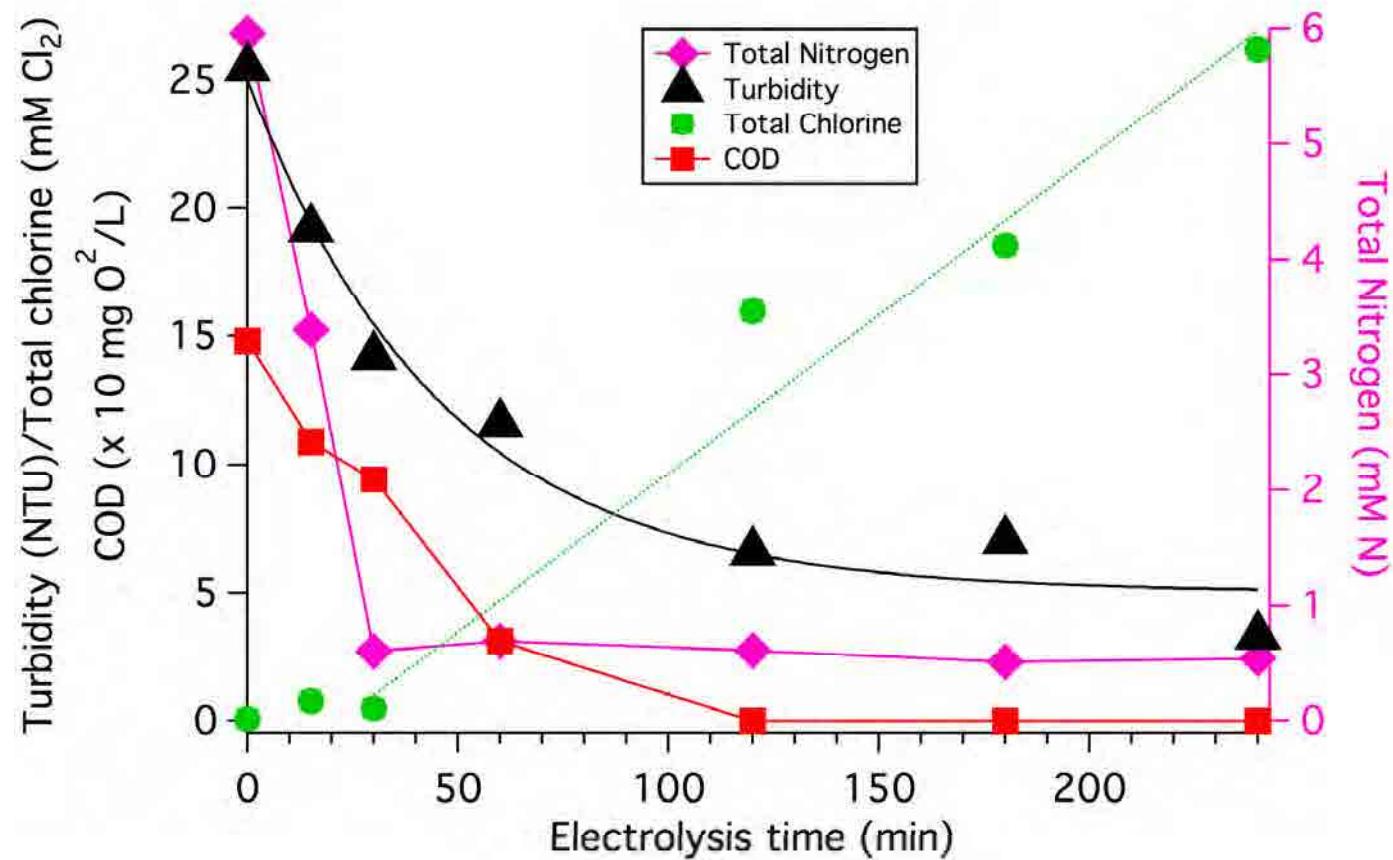








Toilet+City
 wastewater
 3.5 V
 @ 32 A/m²,
 30 mM NaCl

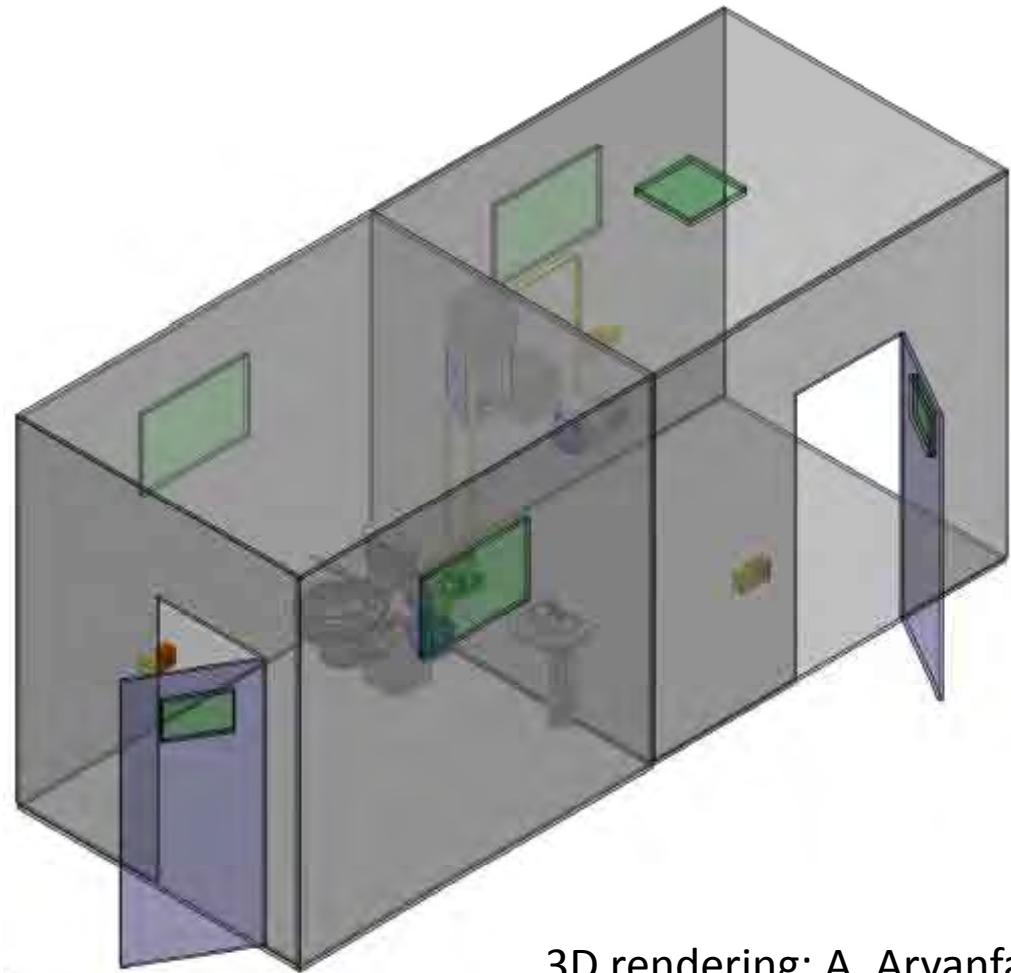


<
 toilet wastewater
 3.5 V, current unknown

3 pre-alpha prototypes

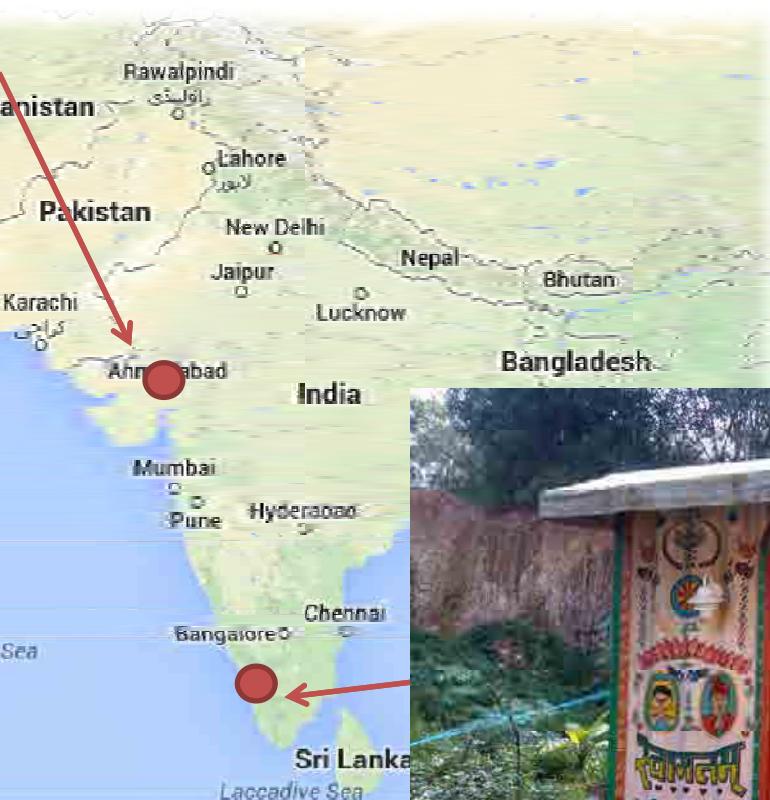
- Caltech campus (2012)
 - 30 ft. long with bathroom included, 1 reactor
 - Separate urine path for Microbial Fuel Cell tests
- Ahmedabad Municipal Park (Caltech-ERAM)
 - 10 ft. cubic container (treatment system only)
 - Screening pit between eToilet and Caltech unit
- Mahatma Gandhi University (Caltech-Kohler)
 - 20 ft. long with bathroom included, 1 reactor
 - Hydrogen combined with biogas possible studies

Prototype on Caltech campus



3D rendering: A. Aryanfar

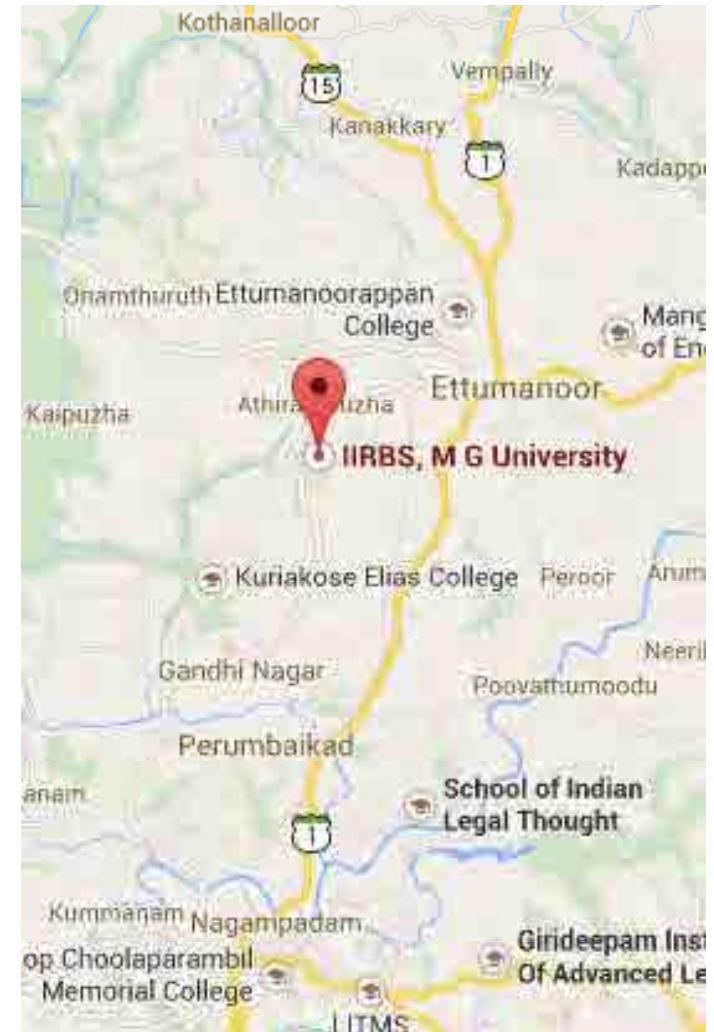
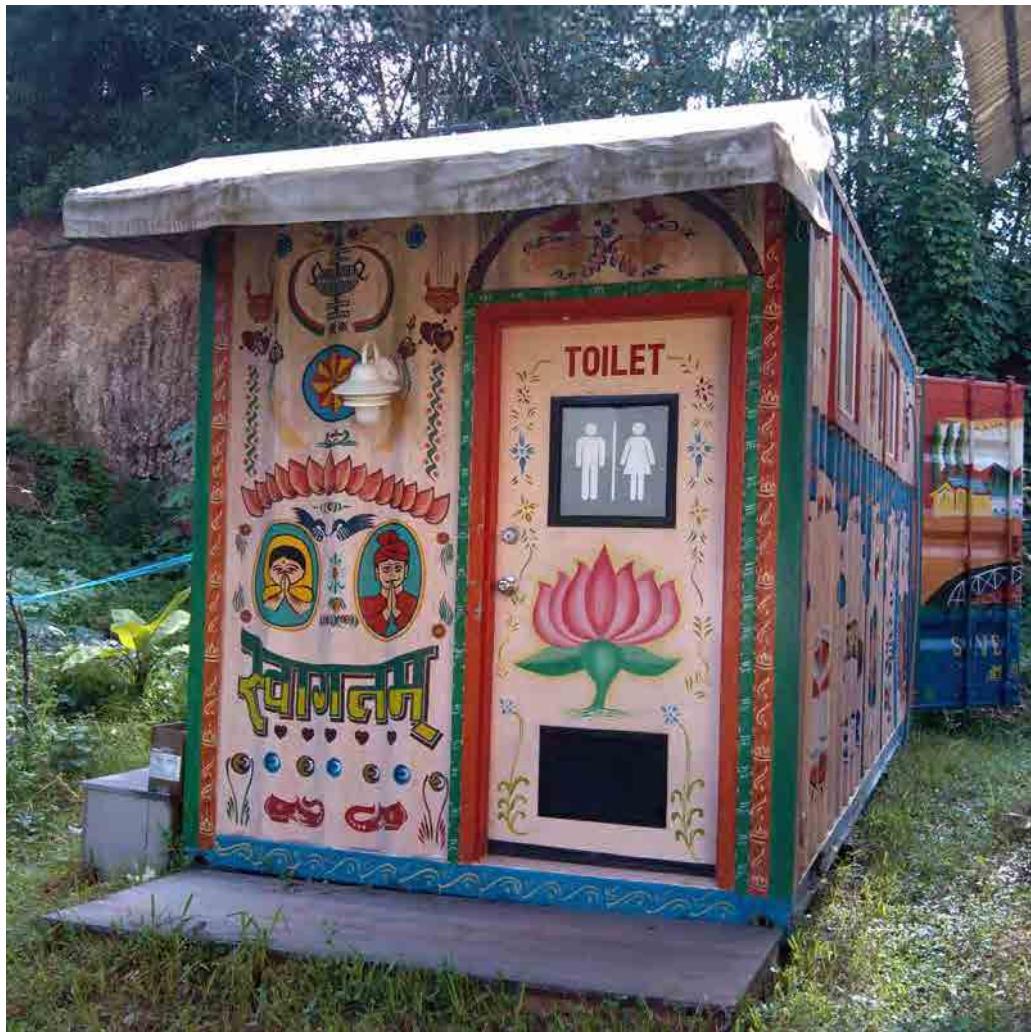
TWO PROTOTYPES IN INDIA



Caltech-ERAM unit



Caltech-Kohler unit





Helminth Egg Detector & Counters

