turning knowledge into practice

A WATERLESS TOILET WITH ELECTROCHEMICAL DISINFECTION AND BIOMASS COMBUSTION

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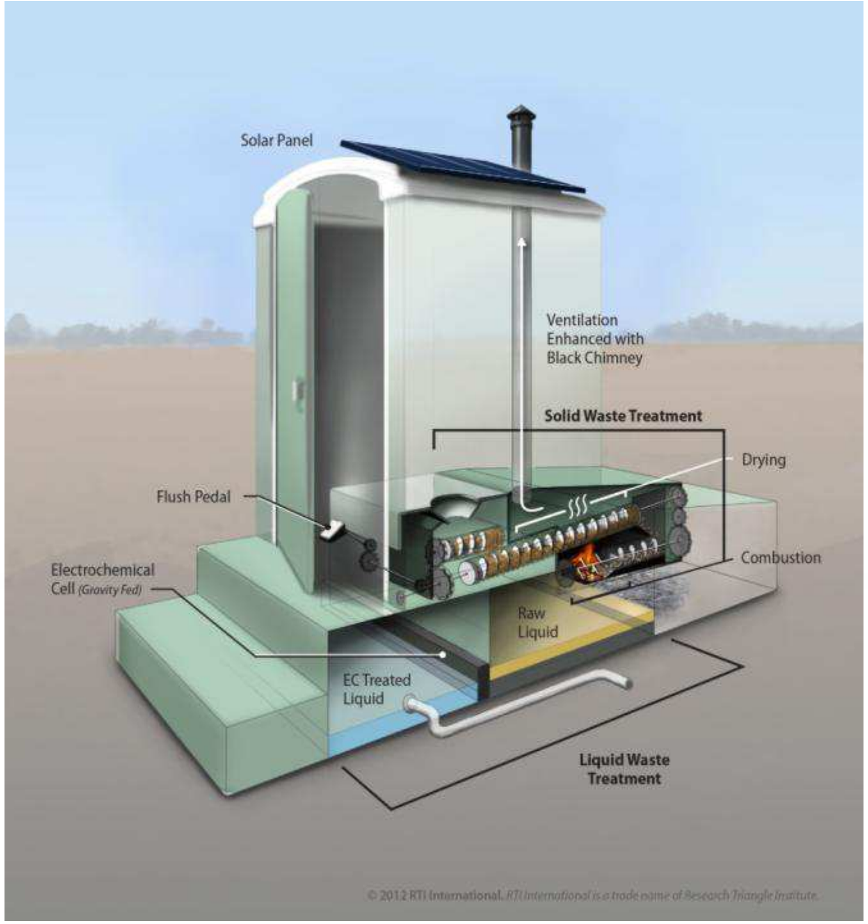
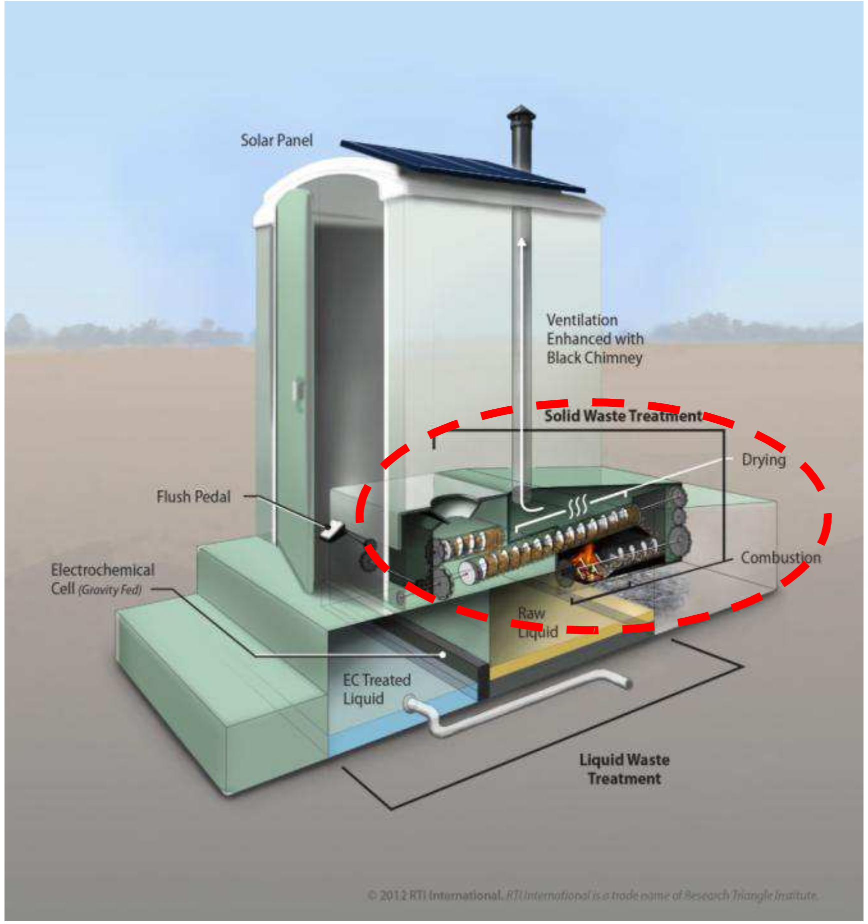
Waterless Toilet Design



System Overview

- *Auger-based solid-liquid separation*
- *Electrochemical disinfection of liquid waste*
- *Thermal drying and combustion of solid waste*
- *Solar and thermoelectric energy harvesting*
- *Modular and scalable*

Solid Waste Treatment



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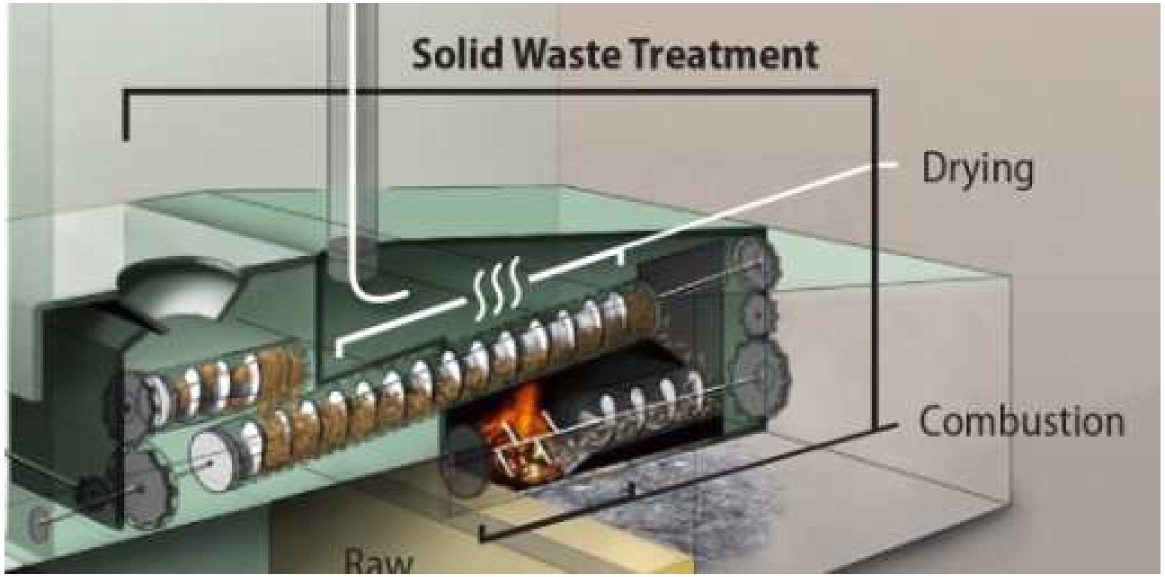
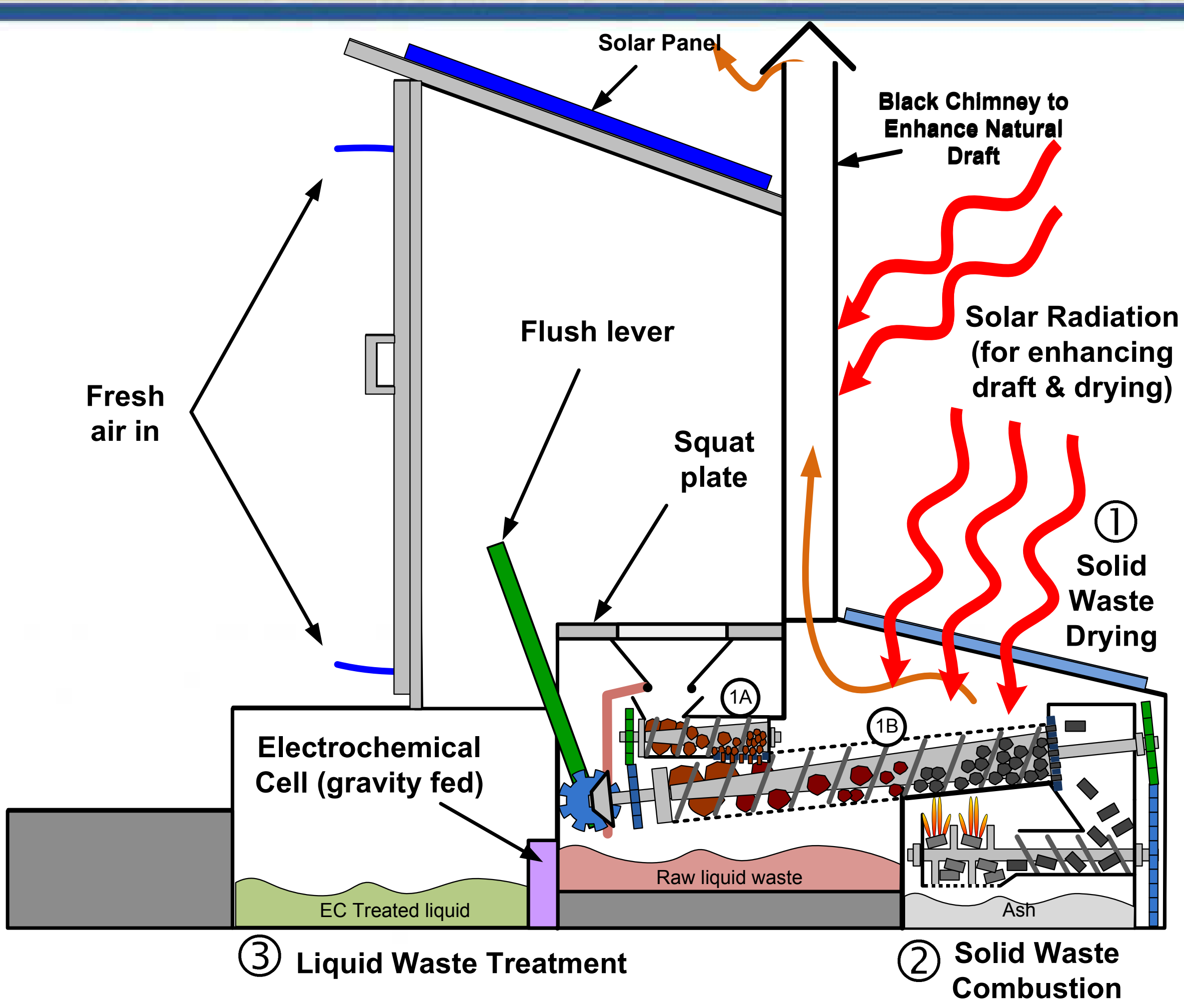
Solid Waste Treatment Module



Module Overview

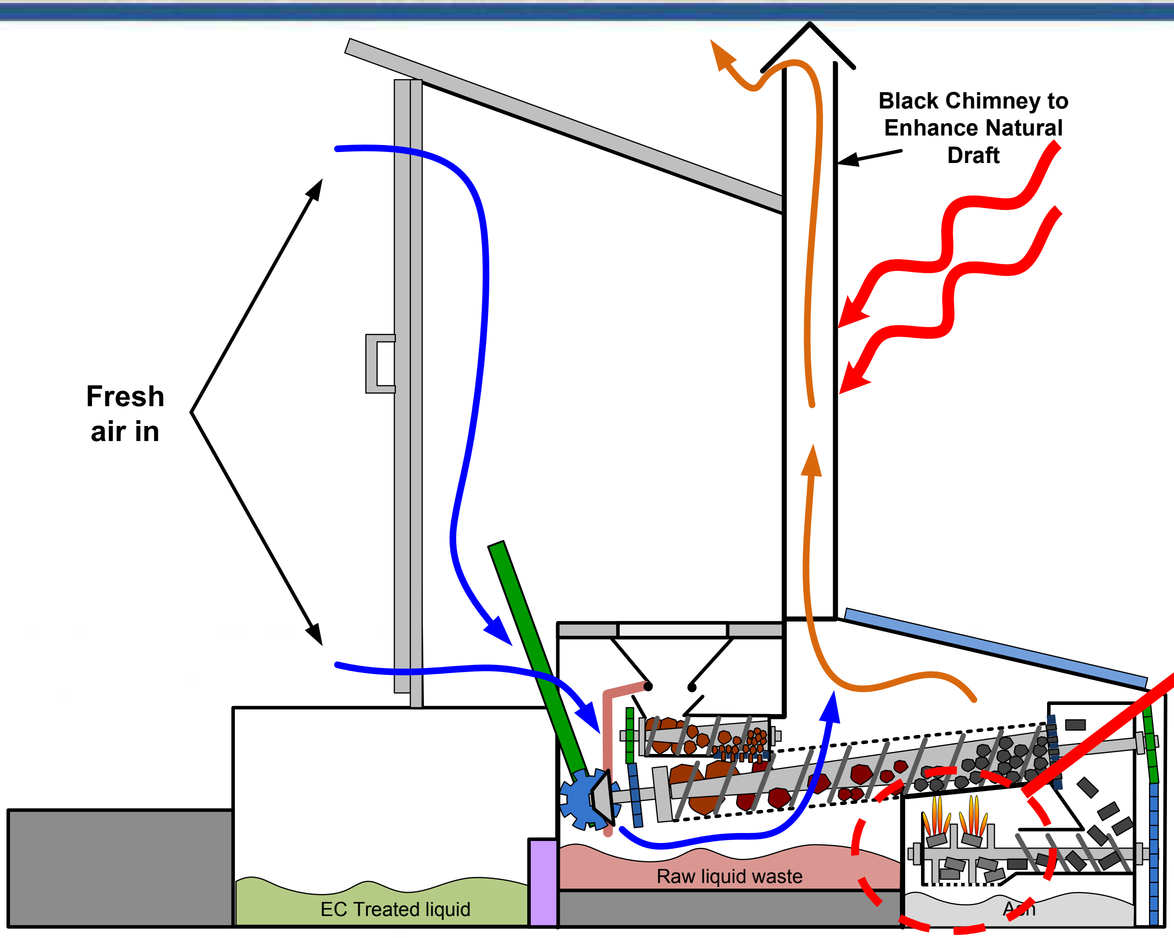
- *Solid-liquid separation and drying*
- *Solid waste combustion*
- *Thermoelectric Enhanced Combustion Add-on (TECA)*
- *Processing steps:*
  - *Convert solid waste to fuel*
  - *Reduce solid waste to ash*
  - *TE power generation and emissions reduction*

Conceptual Schematic of RTI Approach



Conceptual Schematic of RTI's Approach

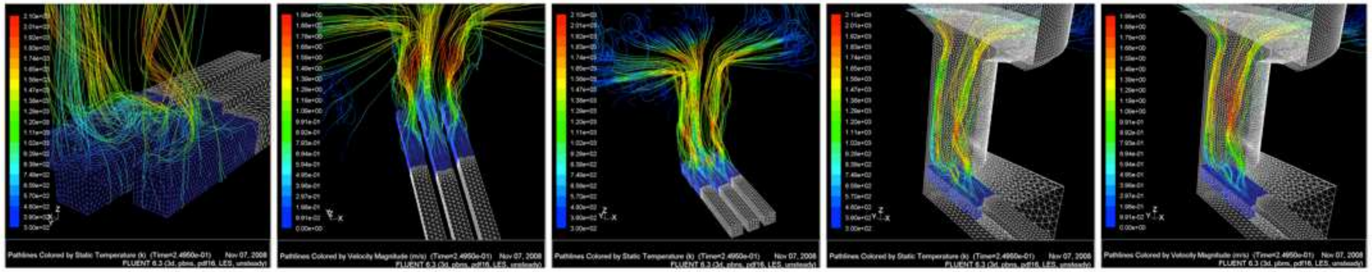
Thermoelectric Air Injection Module



Forced air injection enhances combustion

Colorado State University: Biomass Combustion, Product Test, and Design

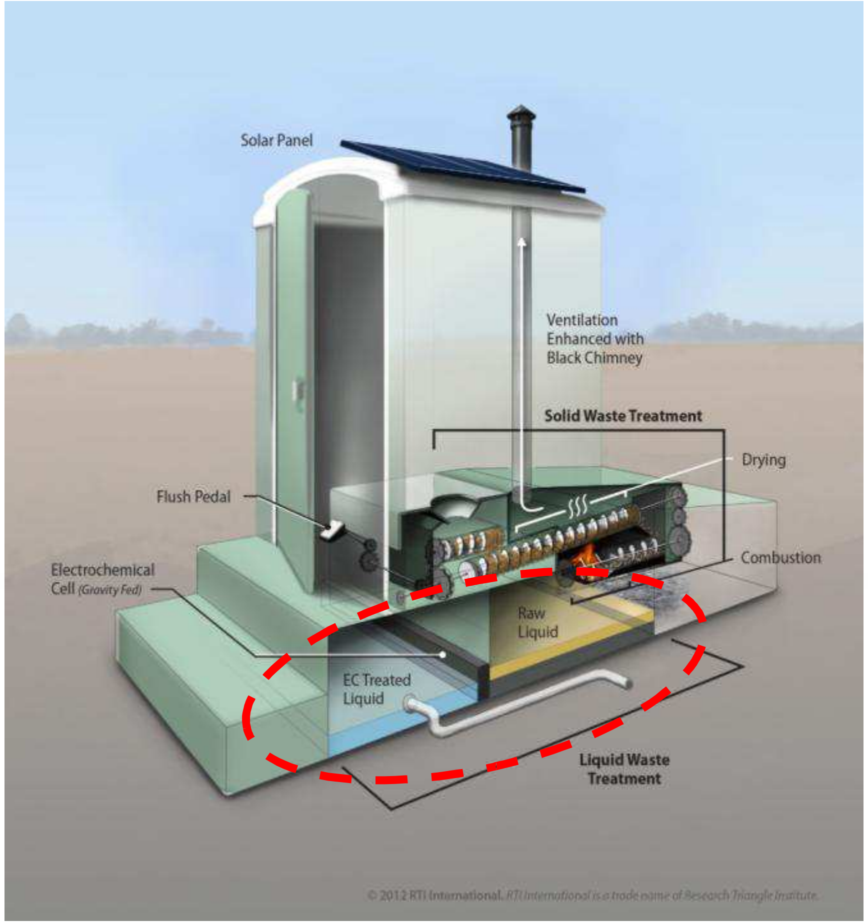
Advanced Modeling for Biomass Combustion



24 hr Test Lab

Over 300,000 biomass combustion units sold worldwide

Liquid Waste Treatment



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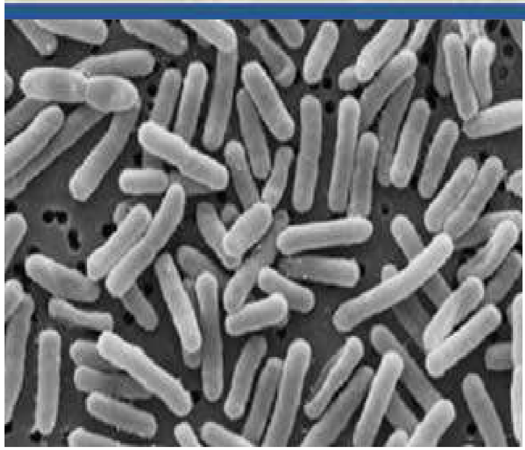
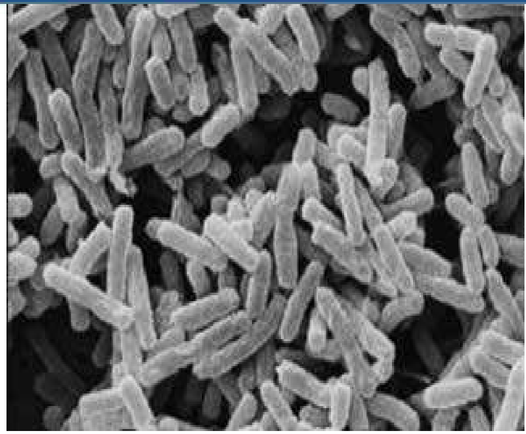
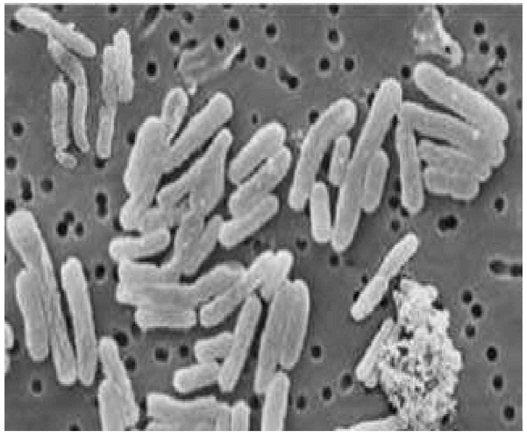
Liquid Waste Disinfection Module



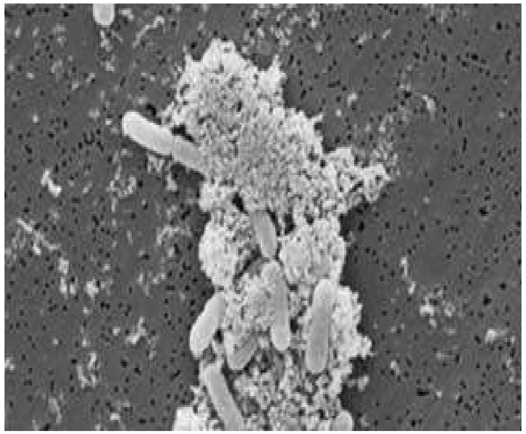
E-Coli



E-Coli after Chlorination



E-Coli after Ozonation



E-Coli after Electrochemical Oxidation

Disinfection using electrochemical oxidation

- *Electrochemical oxidation is more effective at killing E-coli than other treatments.*
- *Attacks cell wall resulting in cell rupture and property modification.*
- *Attacks internal cell components resulting in cytoplasm destruction.*

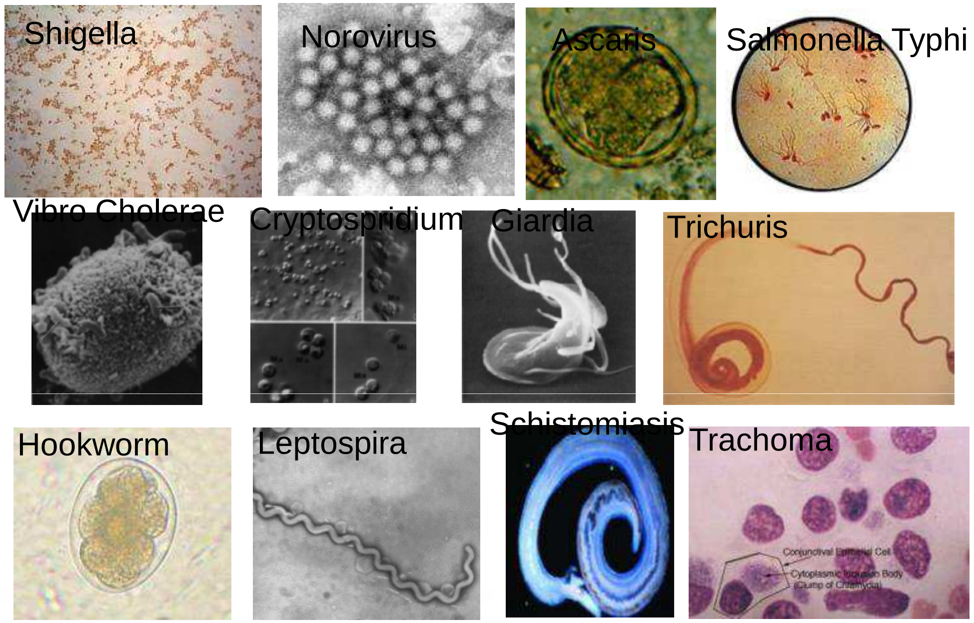
Proc. Chem., Vol. 39, 1421-1426 (2003).

Pathogenic Contaminants in Feces Contaminated Urine

Urine, in general, is sterile.

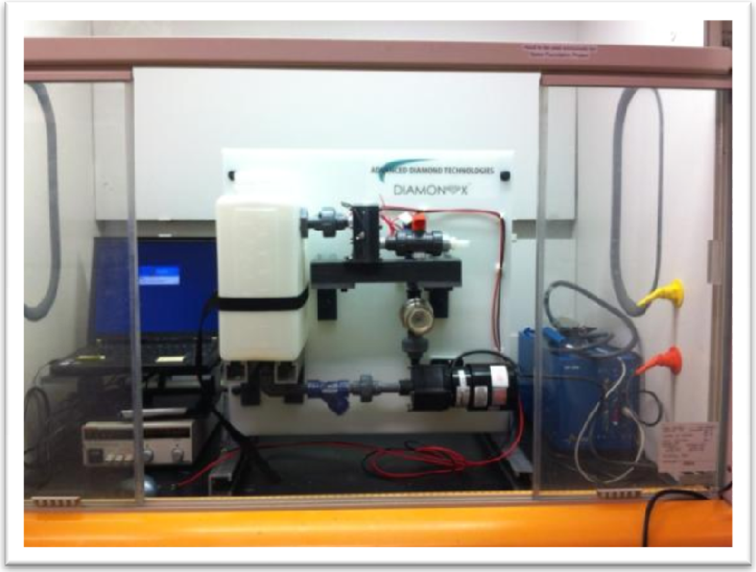
Large number of viruses, bacteria, and helminthes (parasitic worms) present in feces contaminated urine.

>2 billion people affected by pathogens present in feces.



*www.lenntech.com

Electrochemical Disinfection Module



Boron Doped Diamond Electrodes

Inert Surface With Low Adsorption Properties

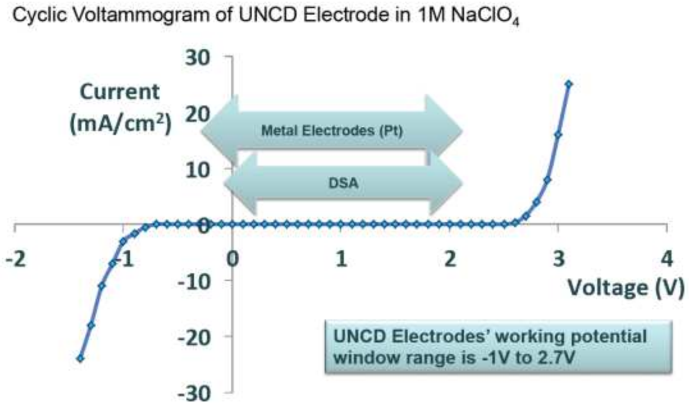
- Results in less electrode fouling.
- Improves efficiency

Corrosion Stability

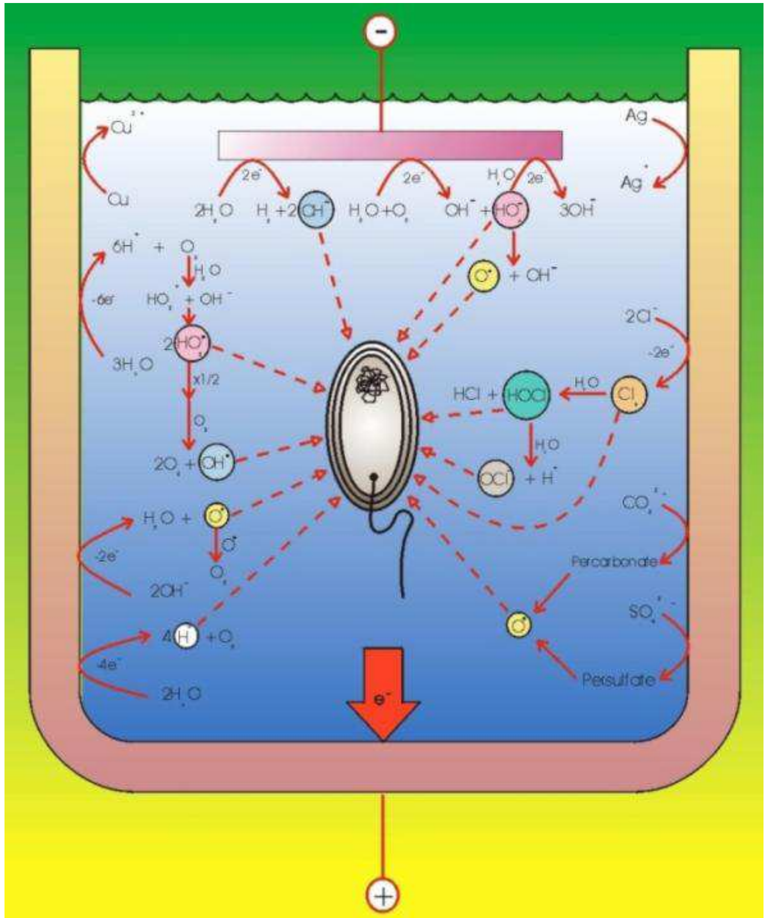
- Electrode surface not damaged during operation.

Extremely High Oxygen Evolution Over-potential

- Large voltage operation window, allowing production of extremely oxidizing species.



Electrochemical Generation of Oxidizing Species



Oxidant	Oxidation Potential (eV)
•OH	2.80
O_3	2.07
H_2O_2	1.77
Hydroperoxyl Radicals	1.70
Permanganate	1.67
Chlorine Dioxide	1.50
Chlorine	1.36
O_2	1.23

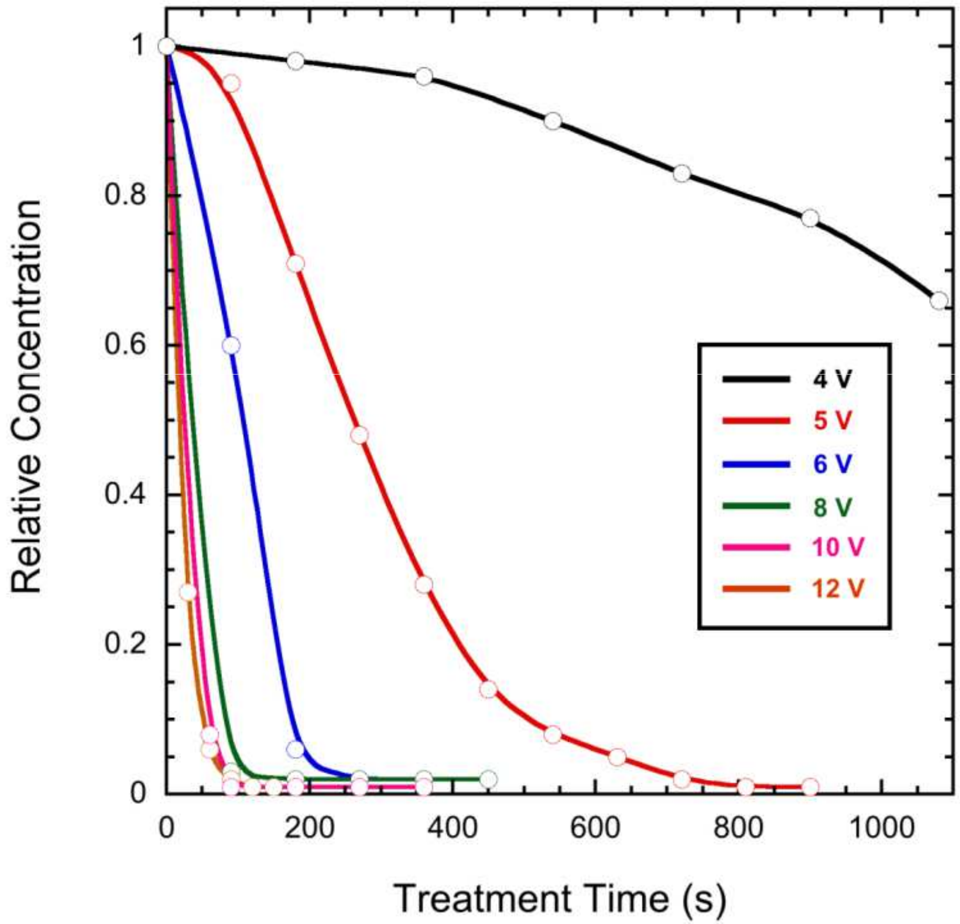
Oxidation using Boron Doped Diamond Electrodes

Large over-potential window allows for production of various oxidizing species.

- Increase in voltage results in production of stronger oxidizers.
- Increase in voltage results in lower power efficiency.

Journal of The Electrochemical Society, **156** (2) E50-E54 (2009)

Preliminary Electrochemical Data



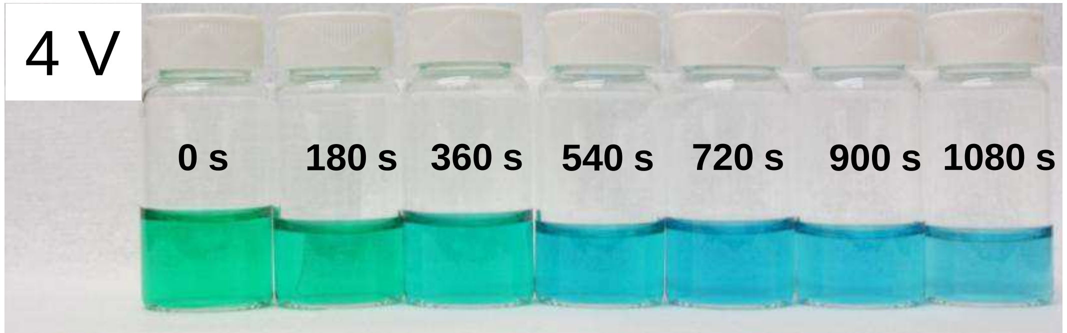
Organic destruction as a function of time.

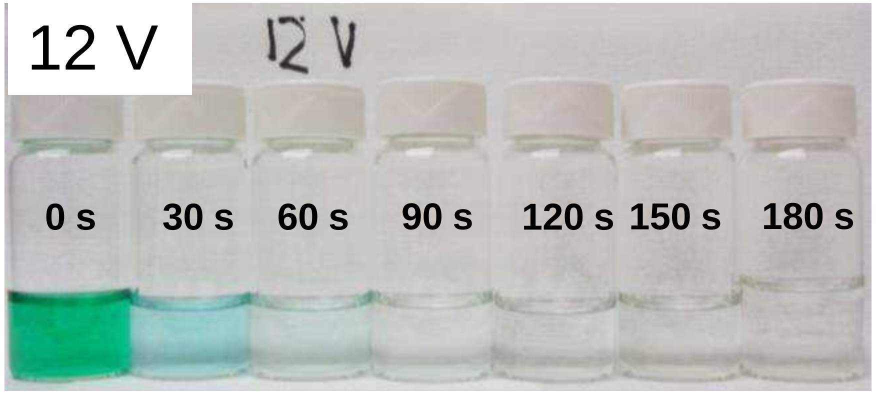
•Physiologic Saline containing a calibrated concentration of organic dye.

•Destruction Rapid at Higher Voltages.

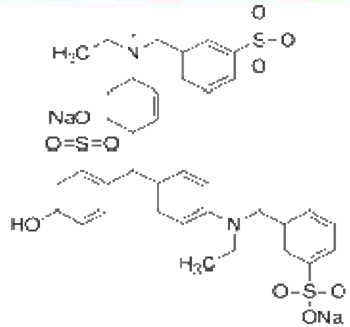
•Disinfection also depends on: Current (conductivity), diffusivities of oxidizing species, and concentration of organic matter, etc.

Preliminary Electrochemical Data (cont.)





Treatment Time



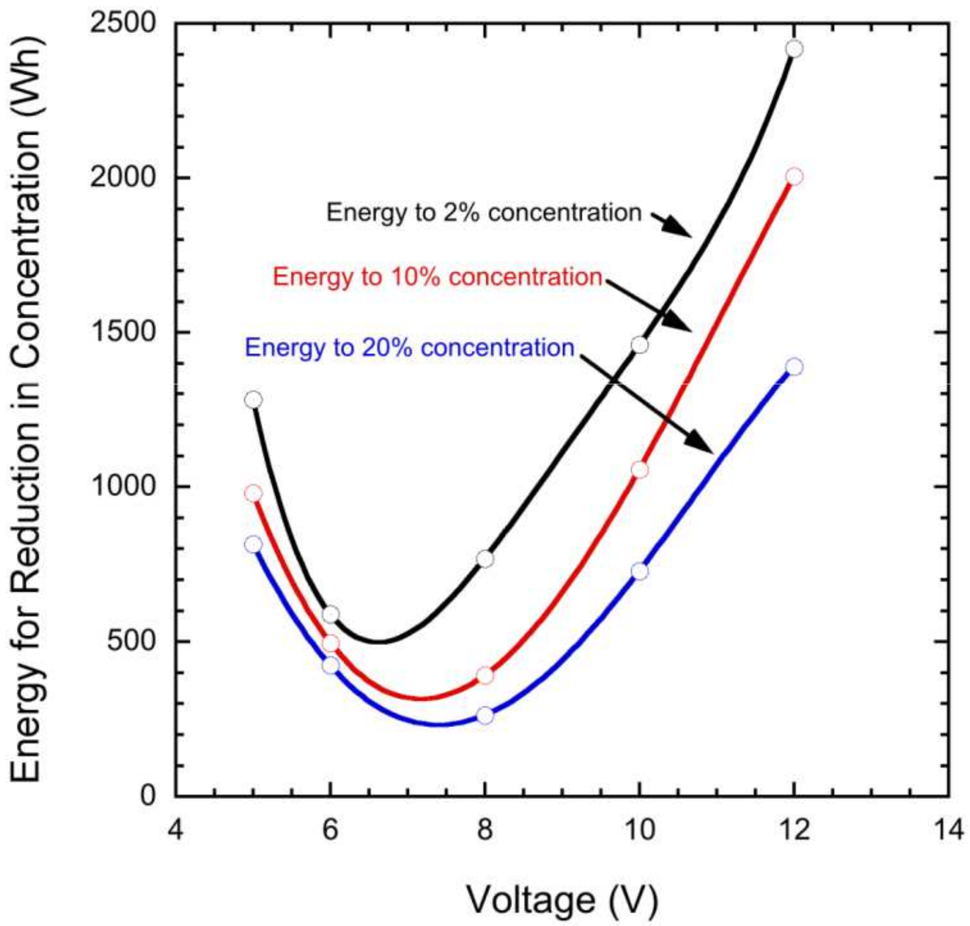
Organic Dye: Food Green 3

Optical detection of organic destruction.

- Physiologic Saline containing a calibrated concentration of organic dye.

- 12V process was significantly faster than 4V process.

Preliminary Electrochemical Data (cont.): Effect of voltage on process energy efficiency



Energy necessary to achieve disinfection.

- Total Reduction Energy (watt-hrs) = Voltage x Current x Process Time.
- 2% color concentration was used to "simulate" disinfection.
- Minimum Energy appears at 6 – 8 V.

Sanitation Technology ✓

Sanitation Technology Adoption ?

Dimensions to Sanitation Adoption

- **Financial / supply chain**: component cost and manufacturing, market structure, cost appropriateness
- **Economic**: market, investments / incentives, policy / regulations, income-generation, affordability
- **Political / public policy**: political will, enabling environment, multi-sector actors
- **Social / cultural**: technology appropriateness, gender and other cultural differences, safety, taboos, prestige and aspirations

Financial / Supply Chain Dimension

- Key questions to be addressed:
  - Component definition and pricing
  - Manufacturing processes/costs, in/out-sourcing production
  - Manufacturing & assembly locations
  - Supply-chain and distribution channels
  - Market structure, openness to trade
  - O&M requirements

Long-term question and modeling work is to consider the cost-savings of radically different technology, e.g. modeling "benefits" of waterless, off-grid toilet will inform financial trade-offs and potential infrastructure investment foregone

Economic Dimension

- Key questions to be addressed :
  - Market size and characteristics
  - Investment requirements
  - Workforce requirements
  - Policy factors: trade, investment incentives, regulation at different levels of government
  - Income-generation potential of by-products of RTT (e.g., fertilizer)
  - Affordability (community & household)

Experience in sanitation marketing (demand approaches) and lessons from communal block toilets are informative for RTT development

Political / Public Policy Dimension

- Key questions to be addressed :
  - Political will: champions and advocates for change
  - Policy and enabling environment: national, provincial, district, village bring goals, levers and enablers
  - Role of actors: public sector, private sector, civil society
  - Regulations, legislation to define standards, use of by-products
  - Business and management model

Enabling environment is important feature for setting incentives, disincentives, outlining roles of actors, and defining champions

Social Dimension

- Key questions to be addressed :
  - Gender-disaggregated behavior, attitudes of men / women
  - Cultural differences across ethnic, linguistic groups
  - Taboos pose risk to technology adoption
  - Safety questions present positive and negative incentives
  - Traditional practices (paper, water, sitting, squatting)
  - Prestige and aspirations, powerful change agents in sanitation
  - Geography
  - Convenience
  - Aesthetics

Other research tells us that cultural traditions, appropriateness, adoption of predecessor technology (sanitation ladder) are each important factors to technology diffusion and adoption

Summary

- Waterless Toilet System:
  - Auger-based solid-liquid separation
  - Electrochemical disinfection of liquid waste
  - Thermal drying and combustion of solid waste
  - Solar and thermoelectric energy harvesting
  - Modular and scalable
- Dimensions of Adoption:
  - Financial / supply chain
  - Economic
  - Political / public policy:
  - Social / cultural:

Acknowledgments

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Thank you.