Low Temperature Ozone Oxidation of Solid Waste Streams

James A. Nabity, Erik W. Andersen & Jeffrey R. Engel
TDA Research, Inc.

John W. Fisher
NASA Ames Research Center

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TDA Research

Overview

- Advantages of oxidizing waste
- TDA approach to waste oxidation
- Pilot scale reactor design & experiments
- Experiments w/ simulated waste streams
- Summary and conclusions

Waste Control is Important!
Especially to Long Term Space Missions

- A critical life support problem facing long-term space missions is the control of solid waste
- Current waste generation models predict about 1.69 kg of waste per CMD
- Unprocessed waste poses a biological hazard to the crew
- Continual exposure to odors from untreated waste is a serious threat to crew health and morale

Summary of Current Methods Used for Waste Control

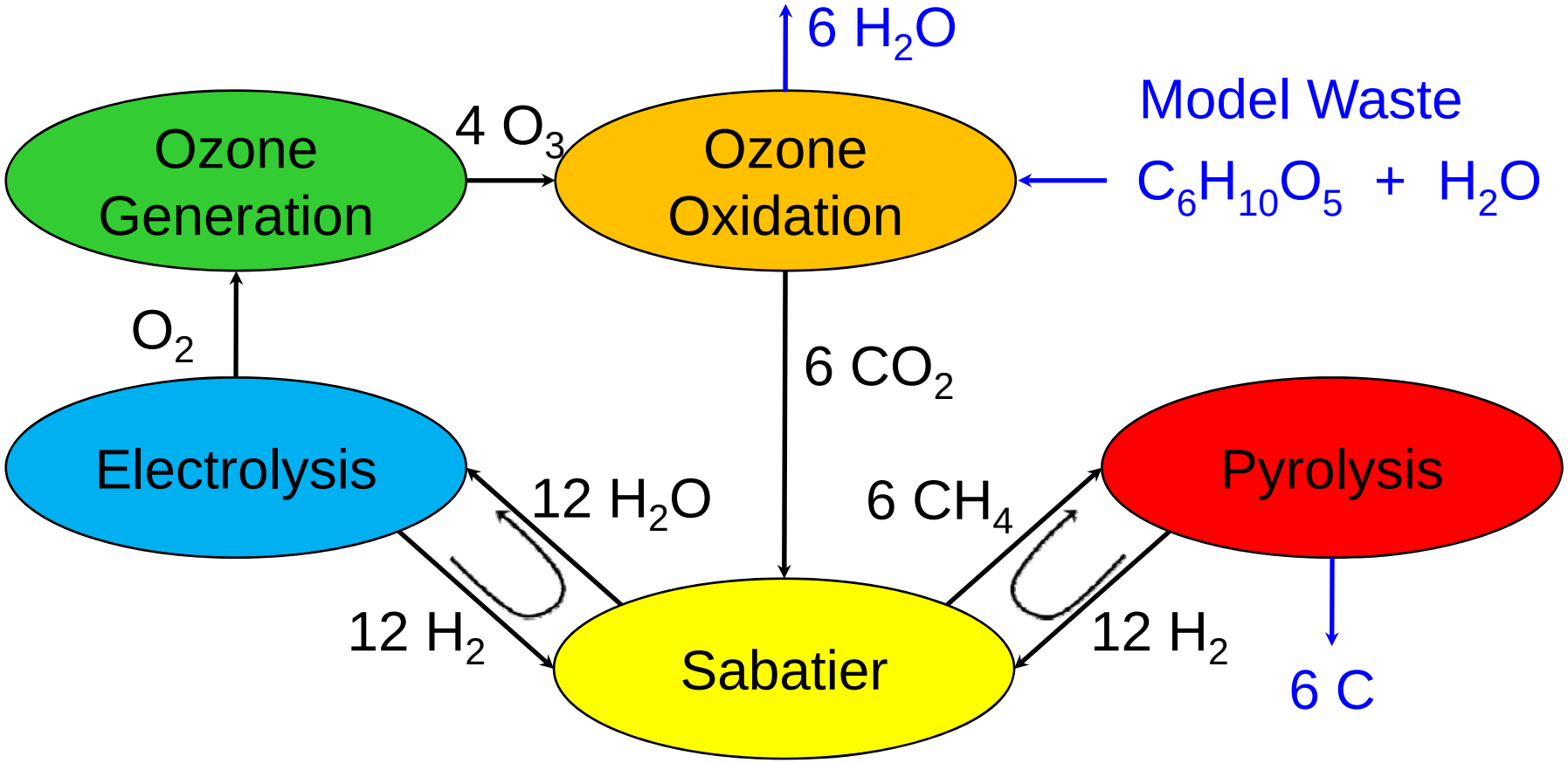
- Strategy depends on mission duration
  - Short term missions can store, compact, or encapsulate waste and do not need to recover resources
  - Long term missions must process the waste and recycle resources – especially water and O_2
  - Oxidation is an excellent choice, since ~0.67 g H_2O can be produced per gram of mixed wastes
  - However, current methods for oxidation still have disadvantages
- There is a need for an effective oxidation process that is rapid and safe

TDA Approach

- Use ozone to convert waste to CO_2 and H_2O at moderate temperature
- The process has several advantages over other methods
  - Ozone will rapidly oxidize a wide range of hydrocarbons
  - Eliminates many hazards
    - does not require high temperatures
    - does not produce high concentrations of NO_X
  - It is safe and easy to use
  - Theoretically, no net consumables are needed

Closing the Loop on Consumables

Example: Cellulose (waste) + 10% water

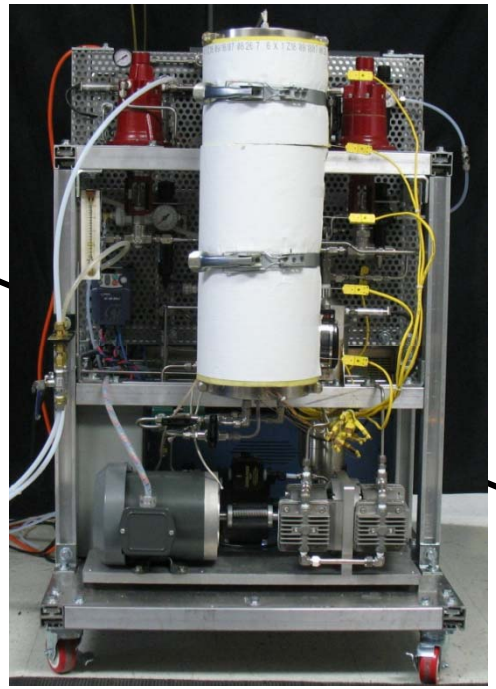


Global System Equation:

$C_6H_{10}O_5 + H_2O + energy \rightarrow 6\ C + 6\ H_2O$

Ozone Oxidation

From This

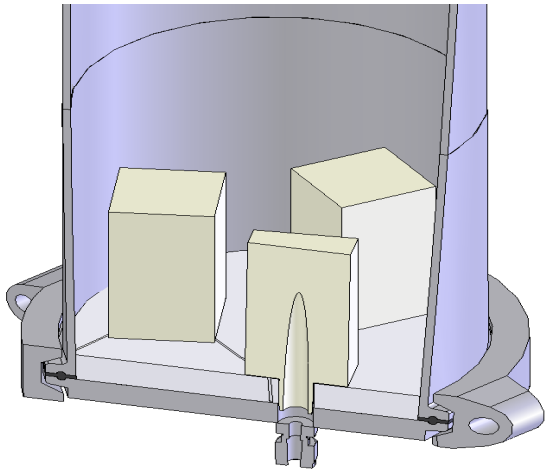


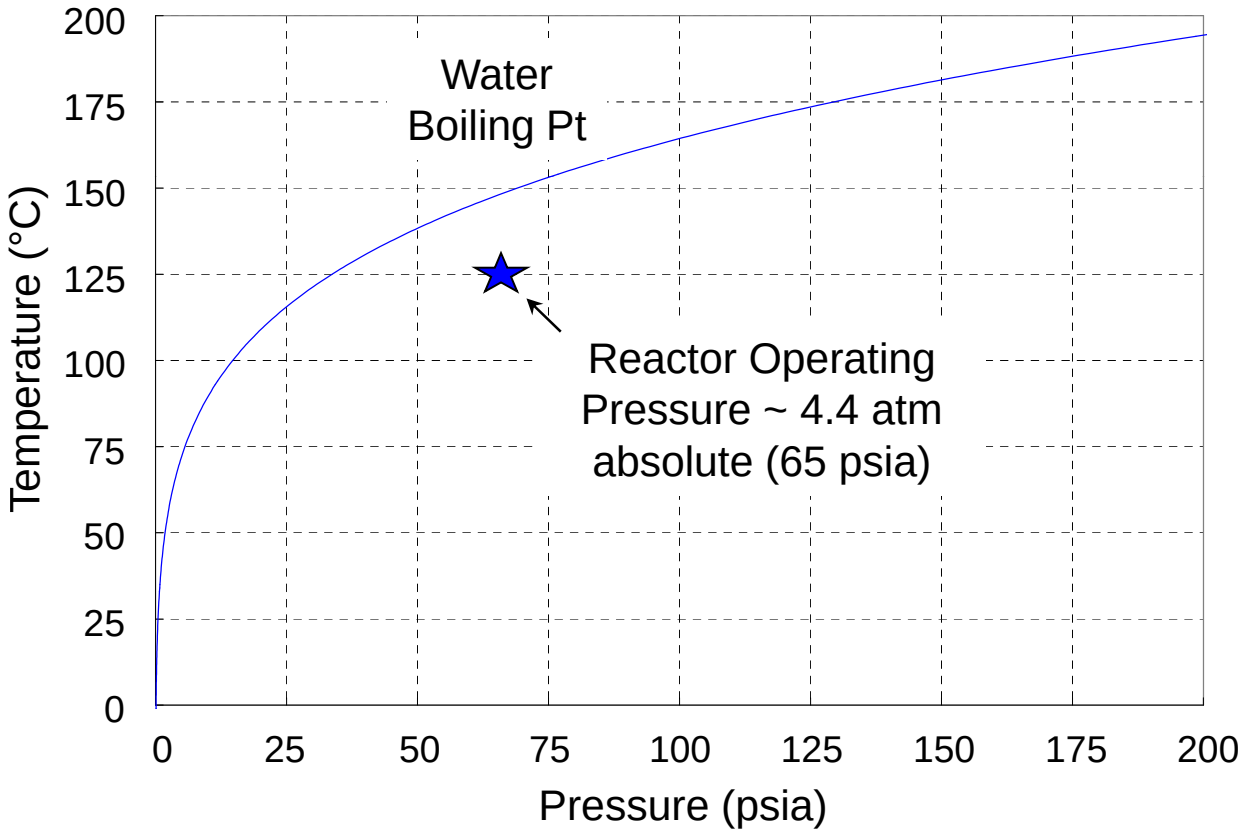
TDA Research
Automated Waste
Oxidation Apparatus

To This

Wet Oxidation Process to Handle Solid Waste

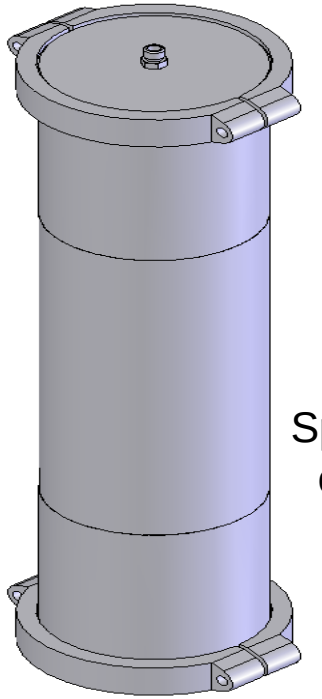
- Low temperature process (~100 to 135°C)
- Stable
- Scalable

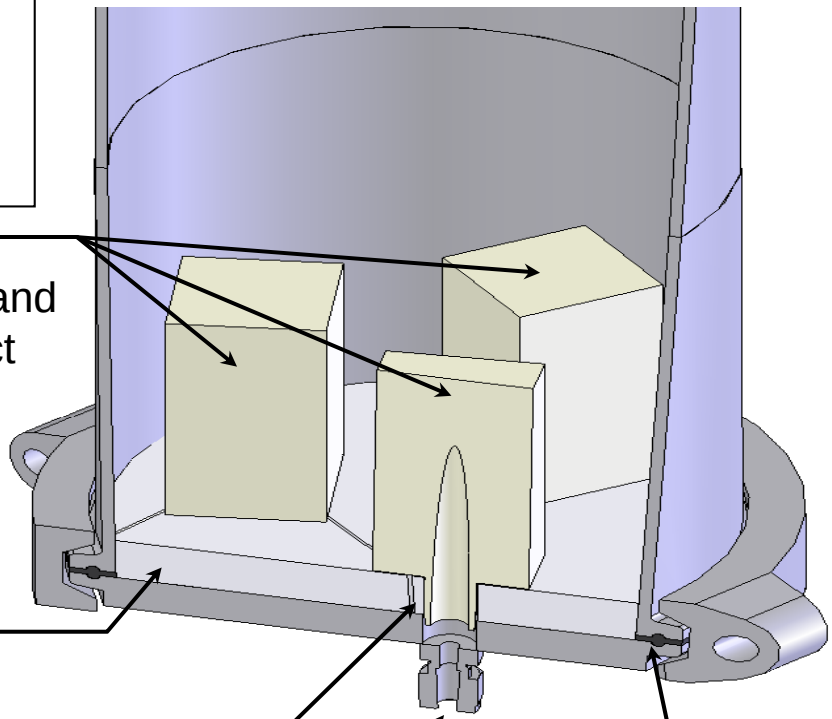




Pilot Scale Reactor Design

- 15.24 cm Diameter, 60.96 cm Length – 11.1 Liter Volume
- 316 Stainless Steel
- Fabricated using 3A sanitary tubing, fittings and clamps
- 13.6 atm max pressure @ 121°C





3 diffusers for enhanced mixing and O_3/waste contact

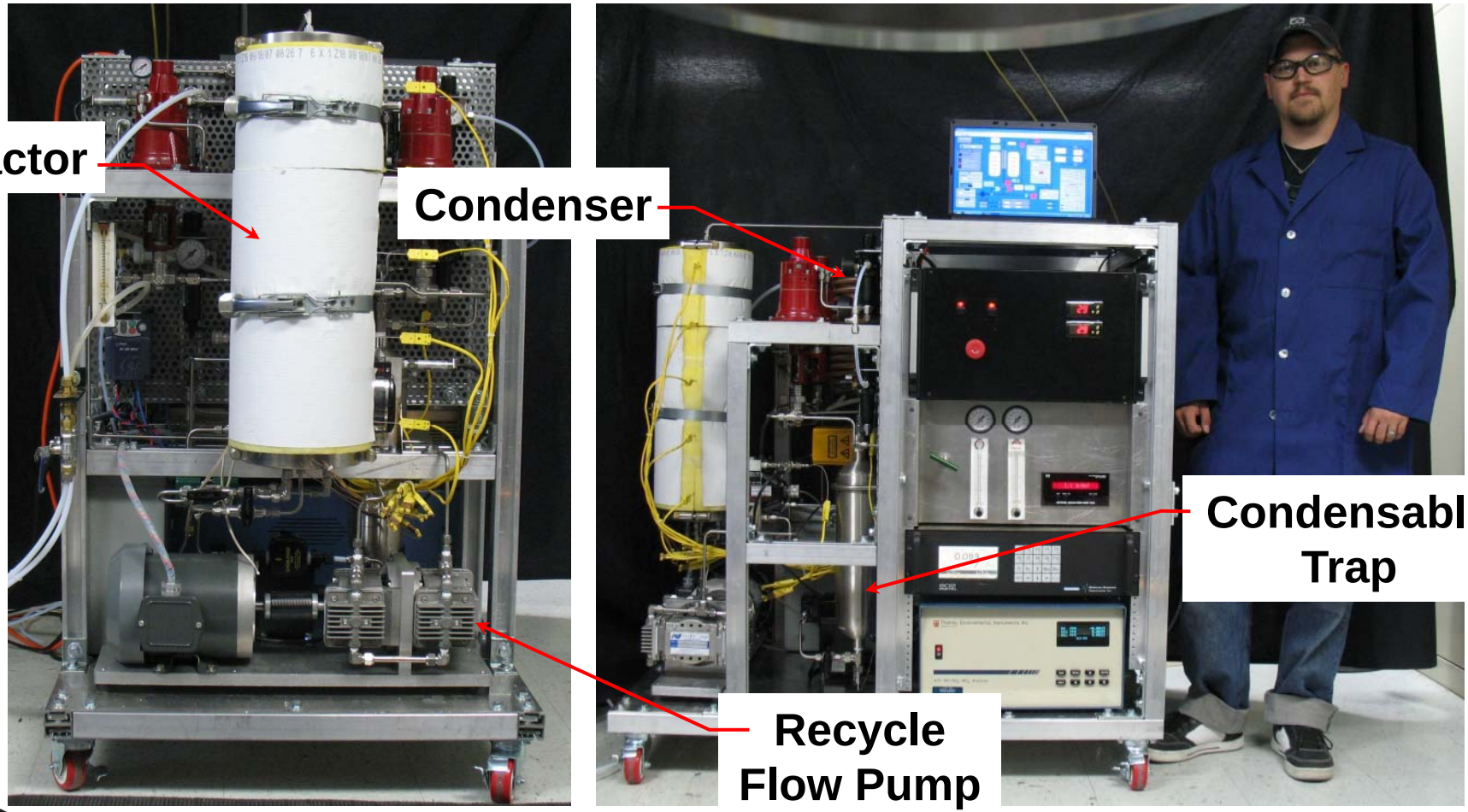
Split PTFE bottom for ease of installation

Holes tapped for easy diffuser installation

O_3/O_2 inlet feed (one for each diffuser)

Fluoroelastomer gasket

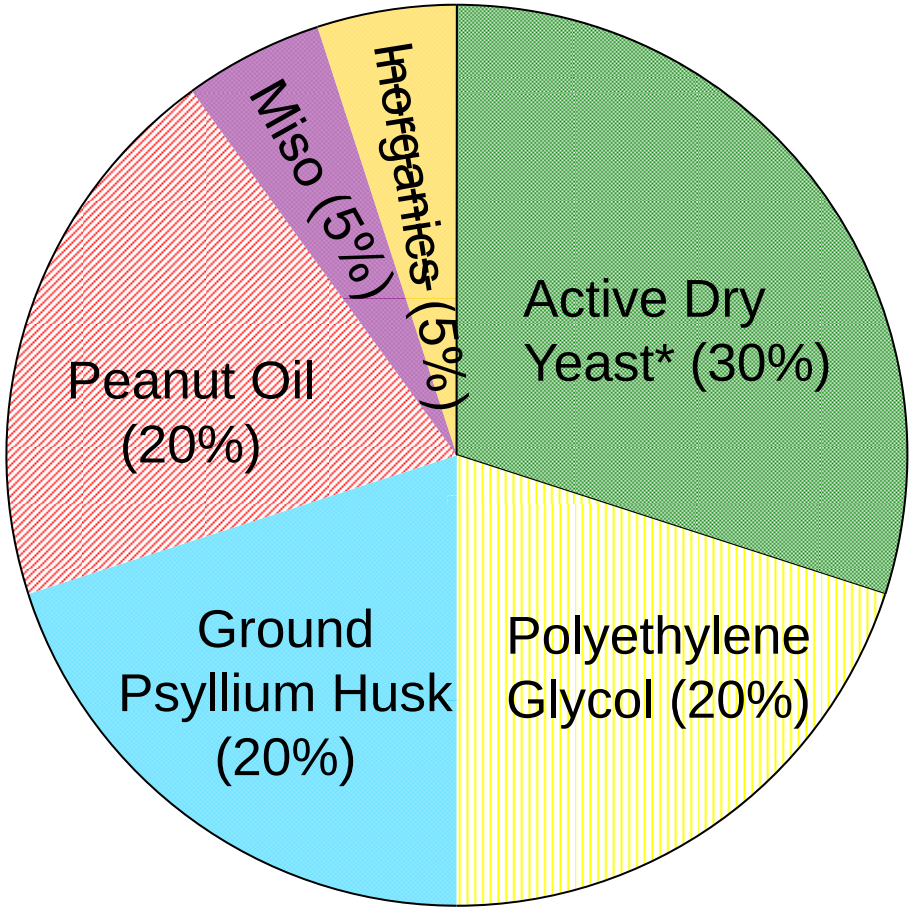
Pilot Scale Wet Oxidation System



Conditions for the Experiment

- Reactor pressure: 4.4 atm (65 psia)
- Reactor temperature: 125°C
- O_2 flow to the ozone generator: 25 slpm
- O_3 flow into the reactor: 1.6 to 4.3 mol/h
- Recycle flow: 20 slpm
- Waste: 100 g of fecal simulant in 5 L of distilled water

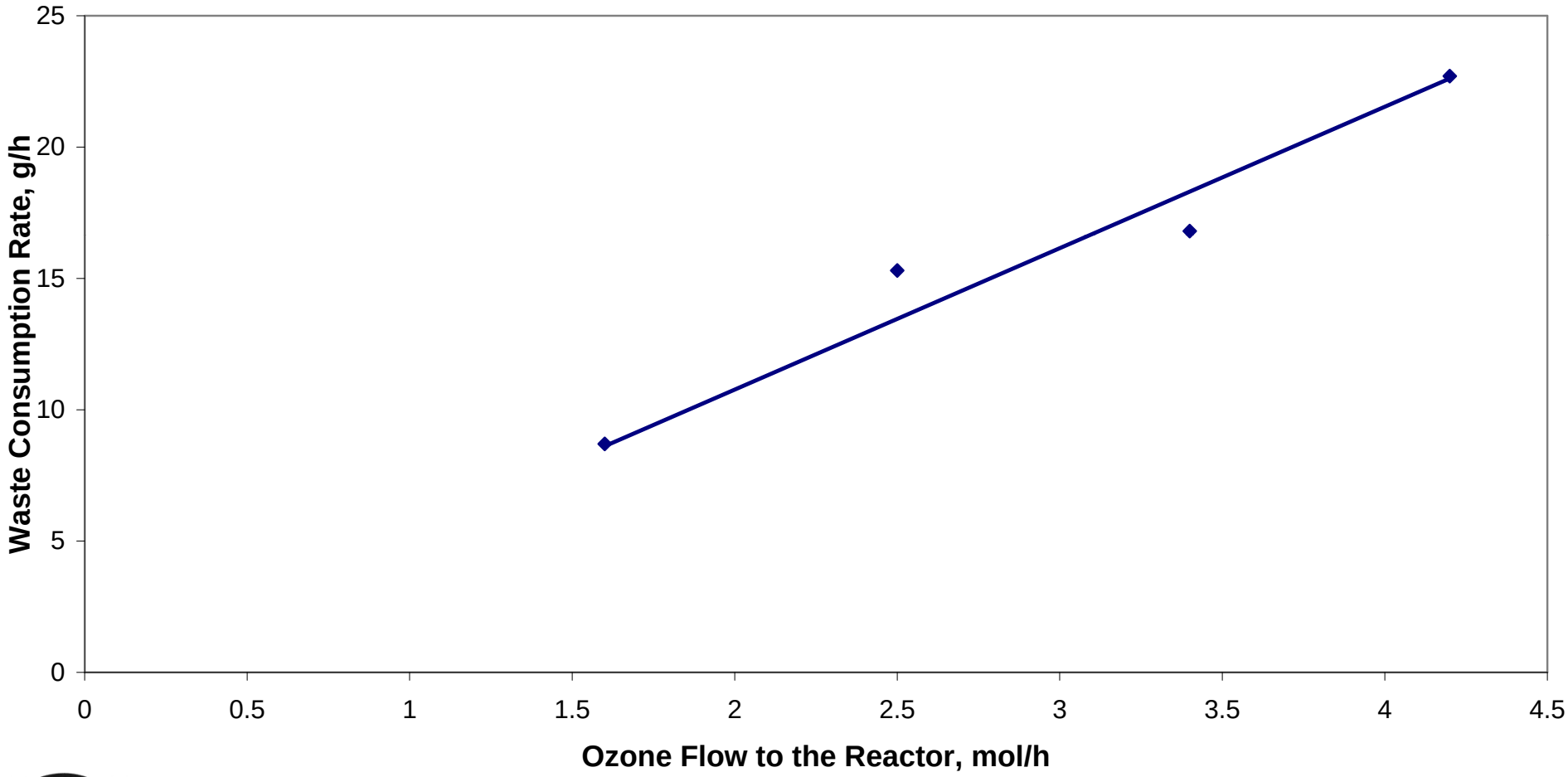
Fecal Simulant Breakdown



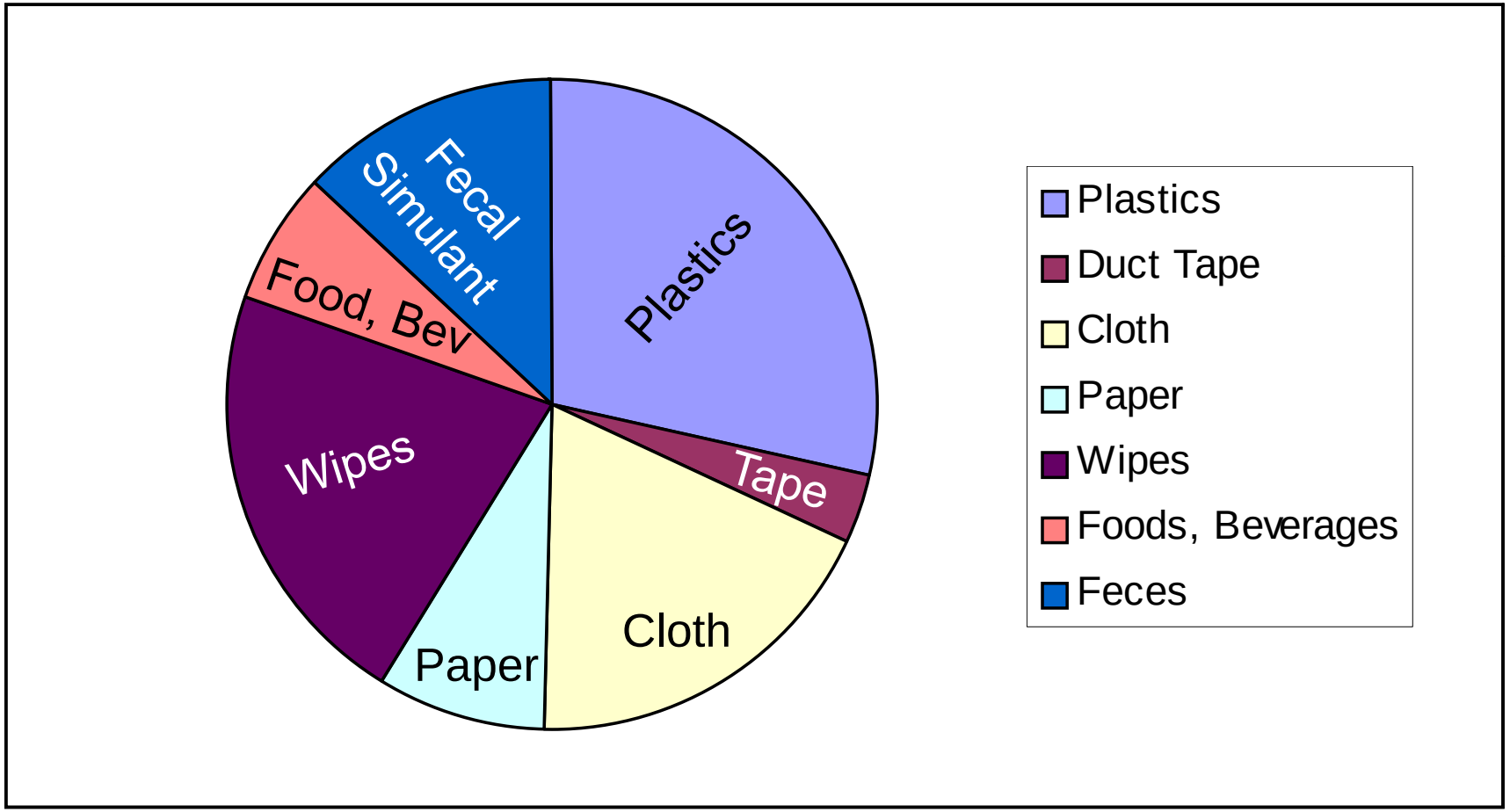
*substituted for E Coli

Ref: Wignarajah, Kanapathipillai, Eric Litwiller, John W. Fisher and John Hogan, “Simulated Human Feces for Testing Human Waste Processing Technologies in Space Systems,” ICES 2006-01-2180.

Effect of Ozone Flow on Oxidation of Fecal Simulant



Composition of Mixed Solid Wastes

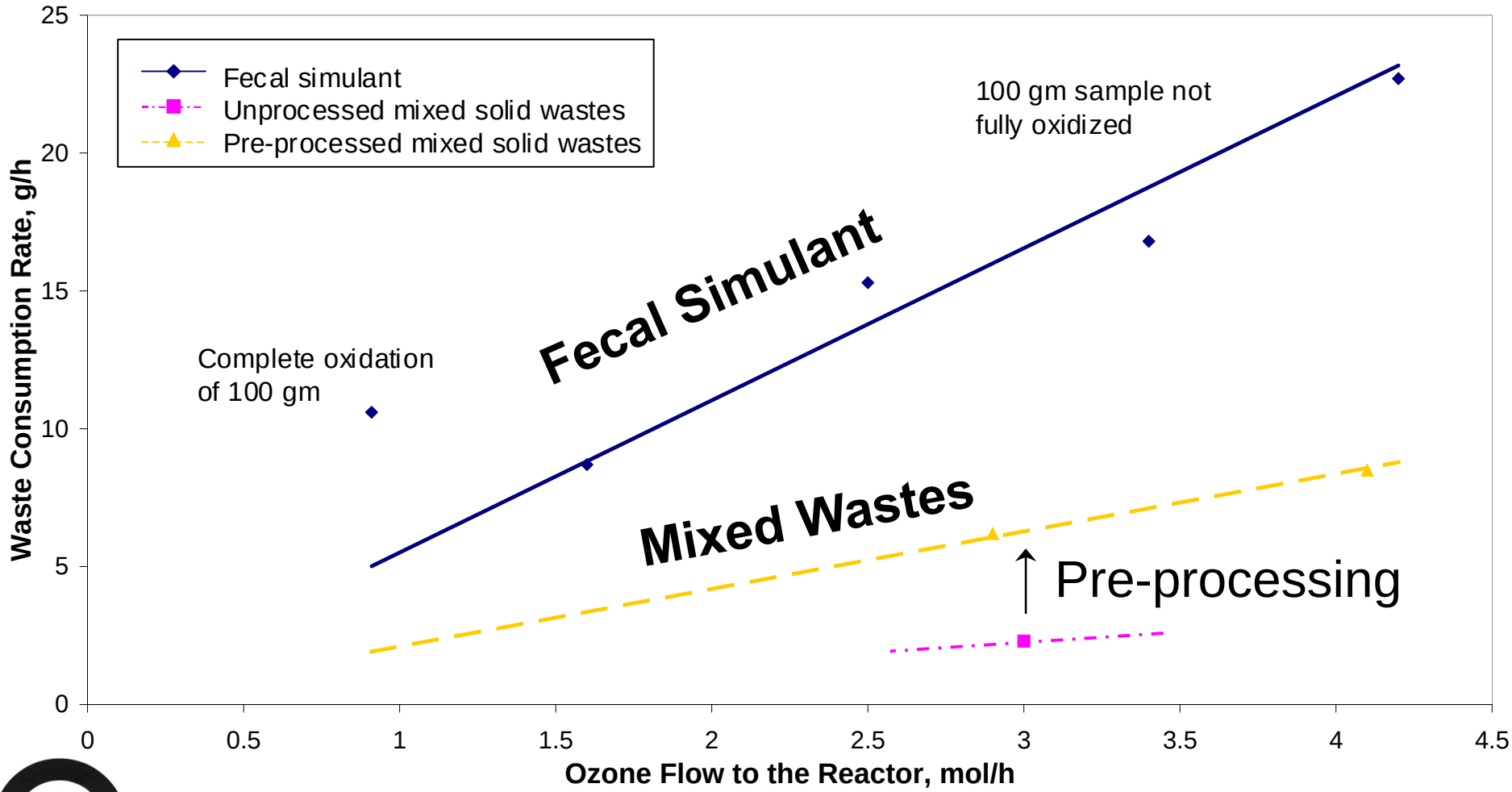


100 gm of Mixed Wastes
w/ and w/o processing

No Pre-processing

Cut into Strips

Ozone Oxidation Results
Mixed Wastes vs Fecal Simulant



Power Budget

Heat Tapes	62.3%
Recycle Pump	7.1%
Ozone Generator	19.0%
Water Transfer Pump	1.5%
Computer	1.2%
Gas Analyzers	8.8%
Total	100%

Summary of Experimental Results

- Ozone can rapidly oxidize wastes at temperatures below 150°C with very high selectivity to CO_2 and H_2O.
  - 22.7 g/h for simulated fecal matter
  - 8.5 g/h for cut up mixed wastes
- NO_x and CO emissions are < 2 and < 1000 ppm, respectively.
- The recycle loop flow can be adjusted to effectively reuse the ozone and conserve oxygen.
- Very reliable apparatus with minimal maintenance.

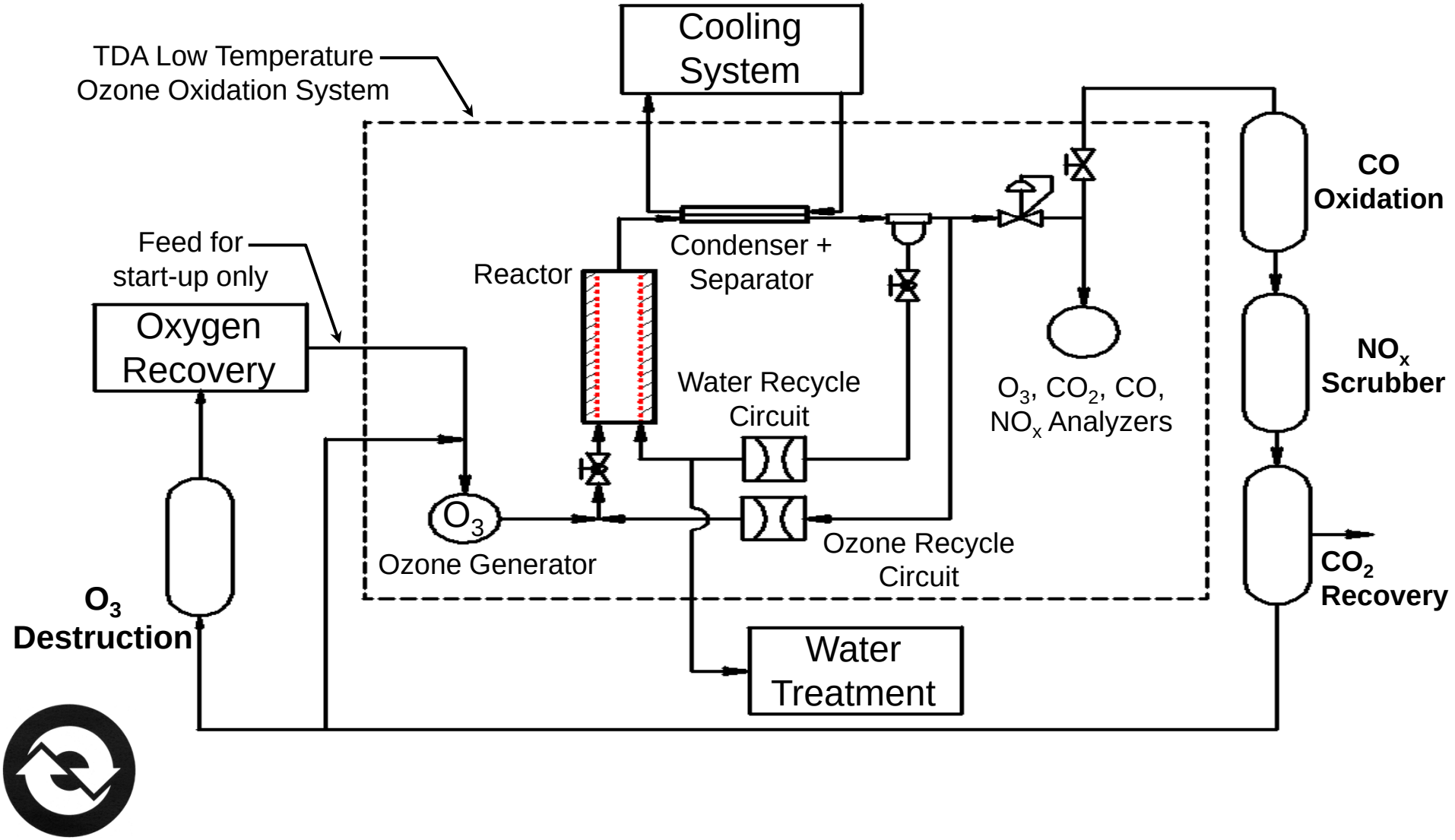
Projected Performance of an Optimized Pilot Scale Rig

- Waste oxidation performance:
  - 36 g/h @ 99.7% destruction removal efficiency
  - 860 g/day
- Resource production: 0.7 to 1.0 kg H_2O/kg waste from Wignarajah fecal simulant (8.4 wt% H)
- Physical parameters:
  - ½-scale for 6 crew members
  - 0.1 m^3 box size and 139 kg
  - 600 W input power
- Consumables: Only the wastes in a closed loop system

System Benefits

- Solid waste destruction: 99.7% based on gas analysis
- Water recovery and production: up to 1.1 kg per crewmember-day assuming mixed wastes w/ 11% water & 6% H content
- Ozone inactivation of microbial organisms and viruses
  - Typically less than 10 minute contact times with between 0.01 – 10 mg O_3 per Liter of water (<10 ppm O_3) needed to lower infectious activity by at least 4 orders of magnitude
  - TDA wet oxidation environment is 1.4% O_3 for over 8 hours

Conceptual Waste Oxidation System



Summary and Conclusions

- Stable and reliable ozone oxidation of waste streams
- Pilot rig effectively consumes solid waste
  - Capable of 0.3 to 0.86 kg / day with high capacity ozone generator
- Generates and recovers water
  - 1.1 kg per crewmember-day assuming mixed wastes w/ 11% water & 6% H content
- Inactivates microbial organisms and viruses

Acknowledgements

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