



## **FOCUSED-PULSED TREATMENT OF WASTE ACTIVATED SLUDGE: A YEAR IN REVIEW**

---

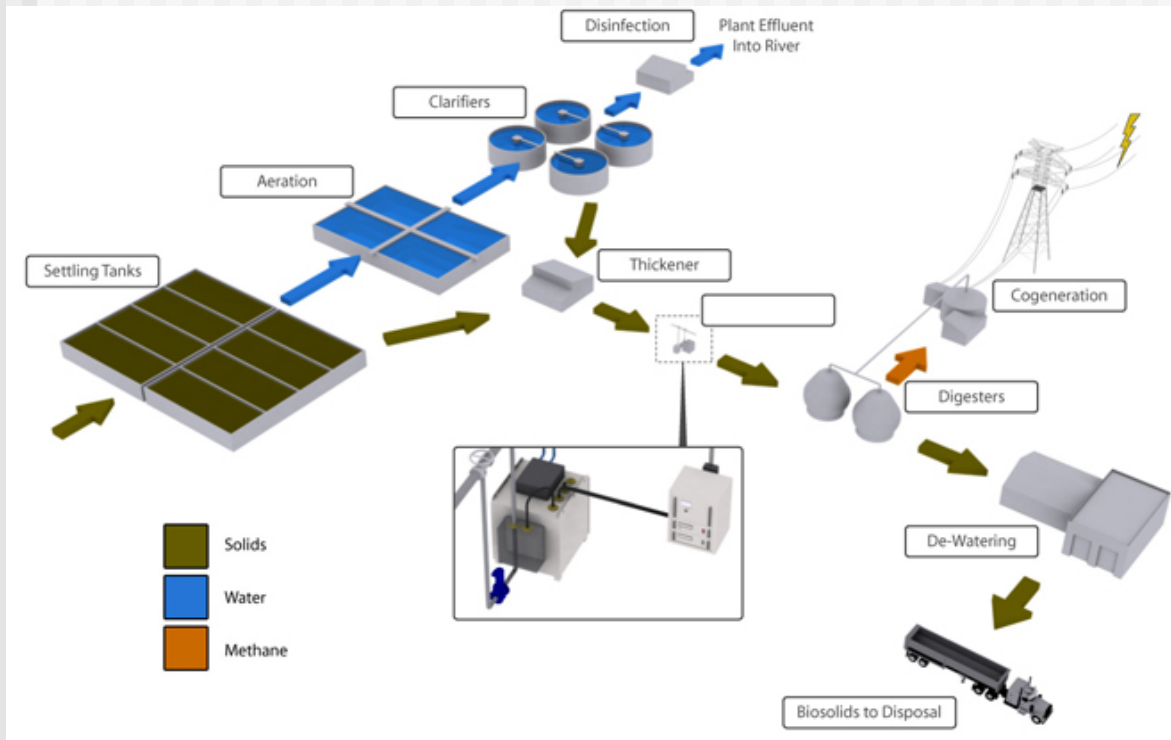
**James E. Banaszak, Ph.D., OpenCEL\***  
**Peter Burrowes, P.Eng. CH2M HILL**  
**Ronald Lopez, P.E., The City of Mesa, AZ**

The 5<sup>th</sup> Canadian Residuals & Biosolids Conference  
Hilton Fallsview Hotel, Niagara Falls, Ontario  
September 13 – 15, 2009



# Introduction

Pretreatment of biosolids for anaerobic digestion is drawing renewed attention



### Limitations of status quo:

- Current conversion of volatile solids in anaerobic digesters is 30-50%; lowest for WAS
- Over 10 million dry tonnes per year of remaining biosolids are generated in municipal wastewater treatment
- Remaining biosolids viewed as a disposal problem, not a renewable energy resource
- Breaching the cellular membrane is the rate-limiting step for anaerobic digestion of WAS
- Pretreatment has been shown effective at lab scale since the late 70's

## The Pioneers of sludge pretreatment – McCarty et al

Gossett, J.M., J.C. Wilson, D.S. Evans, and P.L. McCarty (1978). "Anaerobic Digestion of Sludge from Chemical Treatment," *Journal Water Pollution Control Federation*, 50: 533-542.

Gossett, J.M. and R. L. Belser (1982). "Anaerobic Digestion of Waste Activated Sludge." *American Society of Civil Engineers, Journal of the Environmental Engineering Division*, 108: 1101-1120.

Haug, R.T. (1977). "Sludge Processing to Optimize Digestibility and Energy Production." *Journal Water Pollution Control Federation*, 49(7): 1713-1721.

Haug, R.T., D.C. Stuckey, J.M. Gossett and P.L. McCarty (1978). "Effect of Thermal Pretreatment on Digestibility and Dewaterability of Organic Sludges." *Journal Water Pollution Control Federation*, 50(1): 73-85.

Owen, W.F. and P.L. McCarty (1979). "Improving Digester Methane Yield by Heat Treatment." *SAE Preprints*, pp: 672-679.

Owen, W.F.; D.C. Stuckey, J.B. Healy, Jr., L.Y. Young, and P.L. McCarty (1979). "Bioassay for Monitoring Biochemical Methane Potential and Anaerobic Toxicity." *Water Research*, 13: 485-492.

Stuckey, D.C. and P.L. McCarty (1978). "Thermochemical Pretreatment of Nitrogenous Materials to Increase Methane Yield." *Biotechnology and Bioengineering Symposium*, 8: 219-233.

Stuckey, D.C. and P.L. McCarty (1984). "The Effect of Thermal Pretreatment on the Anaerobic Biodegradability and Toxicity of Waste Activated Sludge." *Water Research*, 18(11): 1343-1353.

### Key findings:

- Confirmed primary sludge relatively digestible
- Typical WAS VSR ~30% or less
- Breaching cell membranes in WAS increased VSR, gas production, and solids destruction

## Sludge pre-treatment technologies

Technology	Description/Scale	Comments
Thermal	<ul style="list-style-type: none"> <li>•High-temperature treatment (150-220°C)</li> <li>•Full-scale success</li> </ul>	<ul style="list-style-type: none"> <li>•Achieve solids reduction</li> <li>•Capital intensive</li> <li>•Energy neutral/negative</li> </ul>
Mechanical (including ultrasound)	<ul style="list-style-type: none"> <li>•Shear, pressure, homogenization, or ultrasonic physical attack of membrane</li> <li>•Pilot scale success</li> </ul>	<ul style="list-style-type: none"> <li>•Achieve benefits of cell lysis at small scale</li> <li>•High energy consumption</li> <li>•Restricted to WAS only</li> </ul>
Chemical	<ul style="list-style-type: none"> <li>•Addition of acids/bases/enzymes/oxidants to attack membrane</li> <li>•Lab/pilot scale success</li> </ul>	<ul style="list-style-type: none"> <li>•Achieve benefits of lysis</li> <li>•High chemical/capital costs</li> <li>•Chemical removal/neutralization</li> </ul>
Electrical	<ul style="list-style-type: none"> <li>•Generation of free radicals by electrolysis of water</li> <li>•Pilot scale demonstrations</li> </ul>	<ul style="list-style-type: none"> <li>•High energy consumption</li> <li>•Discontinued technology</li> </ul>
Electrical – PEF	<ul style="list-style-type: none"> <li>•Electroporation of cell membranes resulting in osmotic lysing</li> <li>•Lab/pilot/full scale</li> </ul>	<ul style="list-style-type: none"> <li>•Demonstrated in multiple labs</li> <li>•Achieve benefits of lysis</li> <li>•Energy positive</li> </ul>

## Main Applications of Pulsed Electric Fields

### Application

### Description

#### Food technology

- FDA-approved alternative to pasteurization for liquid food products
- Scaled for food processing operations
- Significant research history (led by Ohio State University)

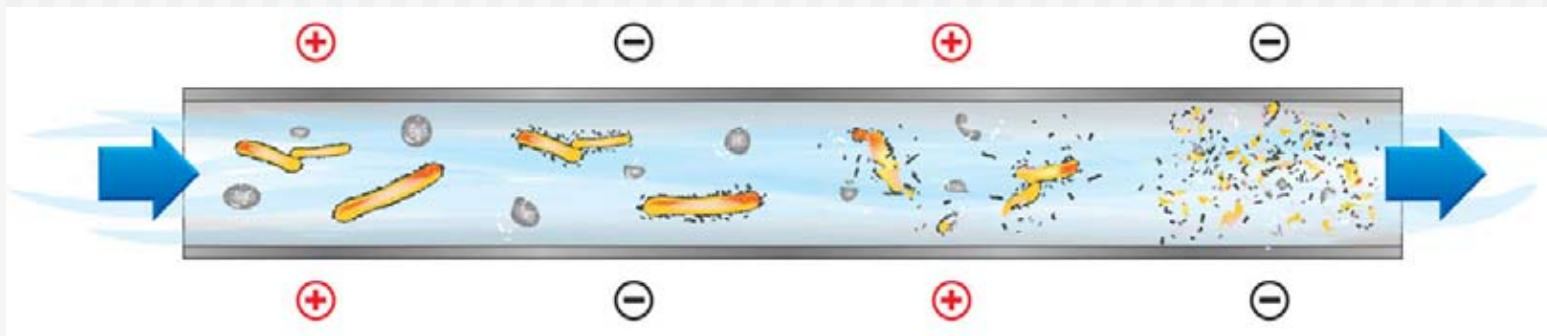
#### Medical/ Biotechnology

- “Electroporation” used for gene and drug transfer in bio systems
- Typically bench scale systems
- Multiple manufacturers of lab electroporation equipment

#### Waste/water/energy

- Acceleration of biotech processes by disrupting cellular membranes
- Industrial scale equipment designed for 24/7 operation
- OpenCEL FP equipment, IP (incl OSU license), and know how

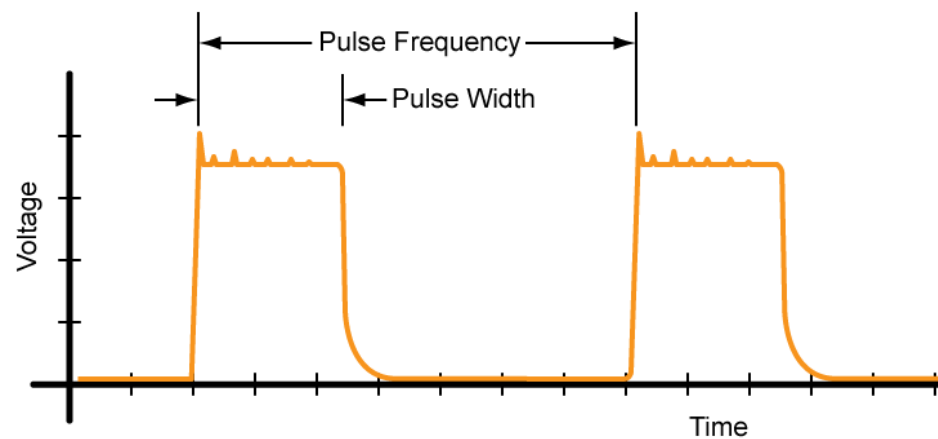
## Focused Pulsed treatment overview



### Key operating parameters

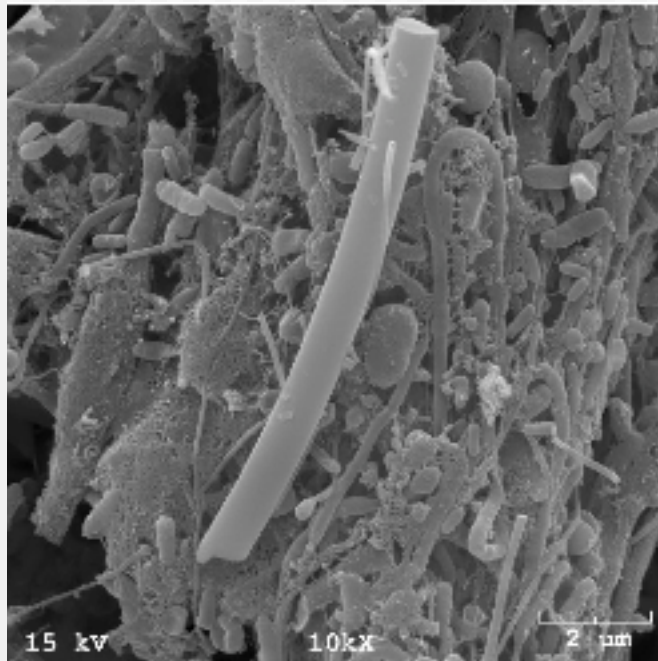
Field Strength	Pulse Duration	Pulse Interval
15 to 100 kV/cm	2 to 15 $\mu$ s	2 to 10 kHz

Mono or bipolar pulse

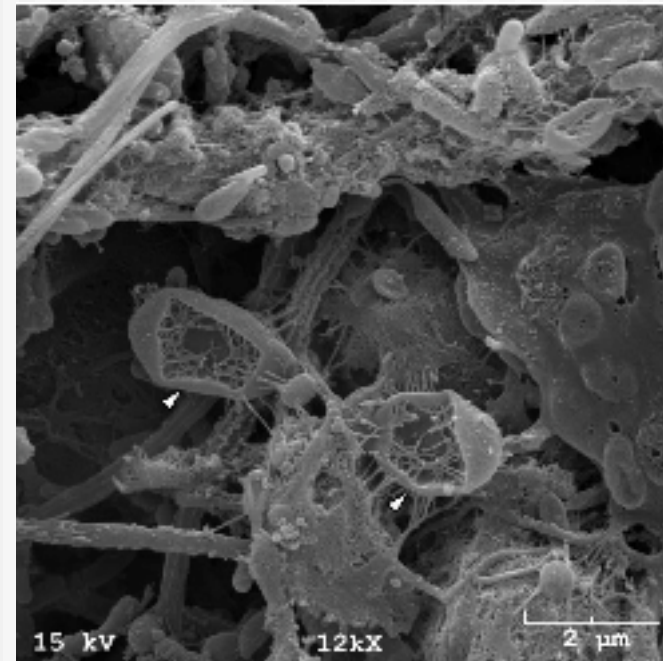


## Mechanism of cell lysis

Before treatment

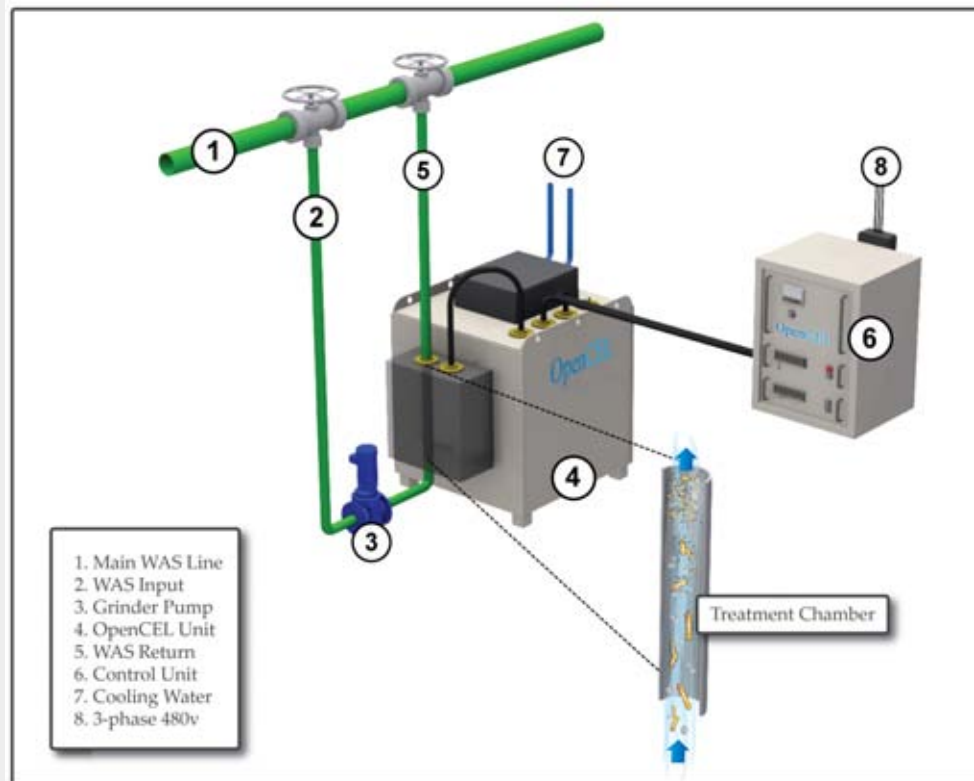


After treatment



OpenCEL treatment causes cell lysis through direct disruption of cell membrane by the electric field, not transfer of energy to another form

## Typical FP installation schematic



- FP system installed downstream of thickened sludge pumps (prior to anaerobic digesters)
- FP system consists of OpenCEL™ components and ancillary equipment
- OpenCEL™ components:
  - Modulator
  - Power Supply
  - Control Rack

# Mesa Northwest Water Reclamation Plant



## Full-scale installation at Mesa, AZ NWWRP

### Mesa anaerobic digesters



#### Operating data:

- Avg. plant flow rate 38,000 m<sup>3</sup>/day (10 MGD)
- Flow rate of thickened PS/WAS mixture of 200 m<sup>3</sup>/day (50,000 gpd)
- Solids content of PS/WAS material between 4% and 6%
- 30-35 day retention time

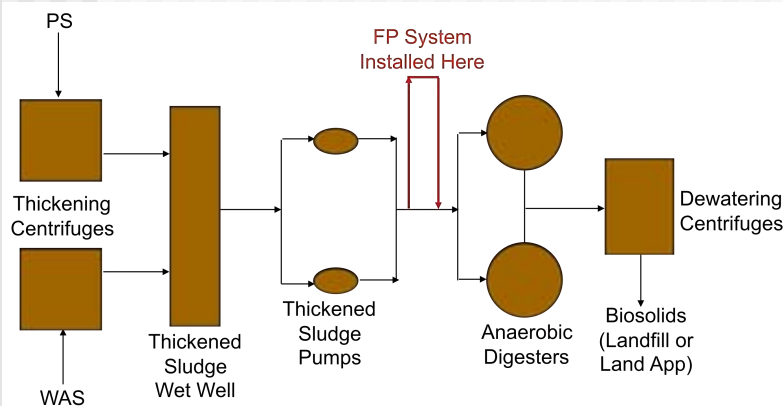
#### Project notes:

- Full-scale commercial installation
- Equipment installed with minimal impact to ongoing operations
- OC unit started in April 2007
- Unit has been treating material continuously since September 2007



# Mesa, AZ NWWRP installation details

The OpenCEL FP unit was installed with minimal impact to plant operations. All consulting engineering and contractors' costs were paid by OpenCEL. OpenCEL owns and operates the equipment for the City of Mesa. The unit was started in April 2007, has operated continuously since September 2007, and has treated over 75,000 m<sup>3</sup> (20 MG) of material.



Power supply

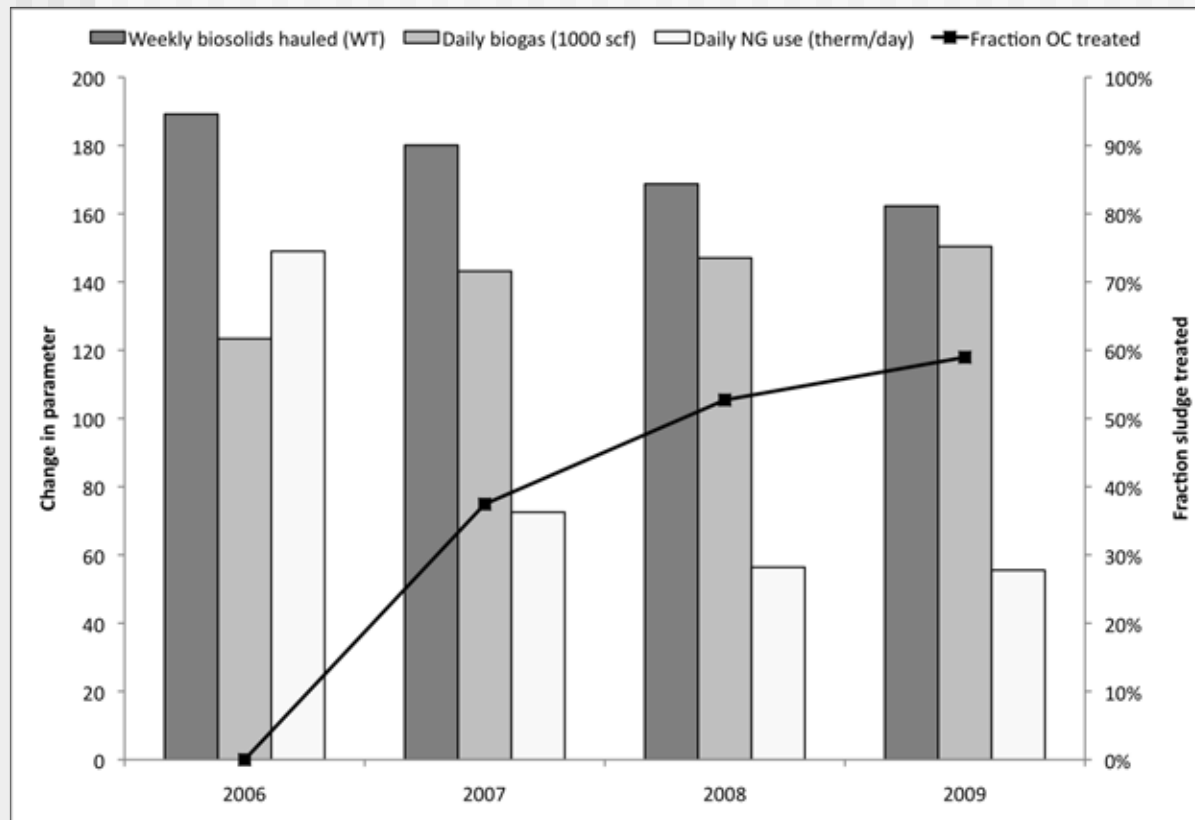


Modulator and treatment chamber



Control system

## Plant performance trends since OpenCEL installation

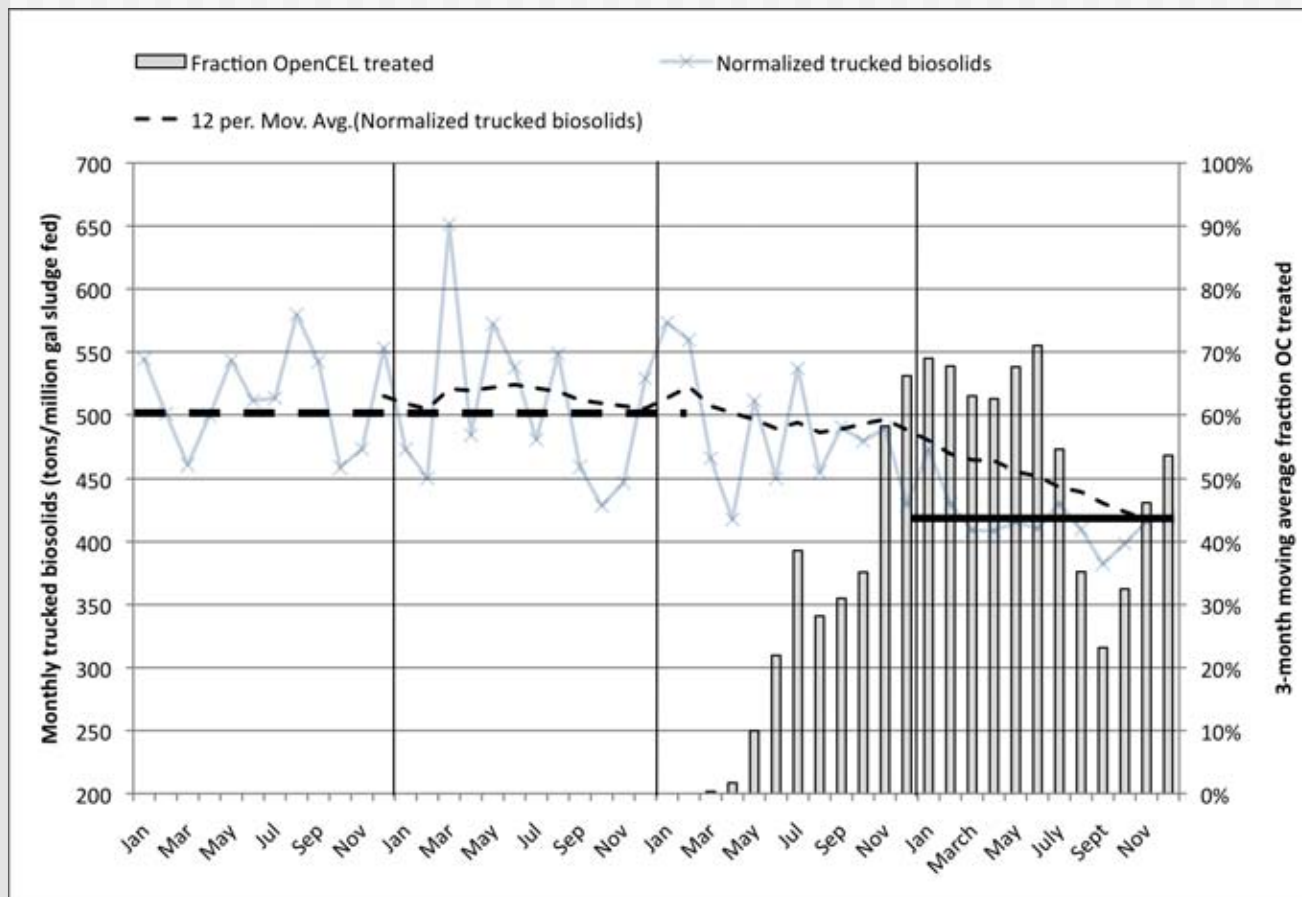


Source: NWWRP operating data

### Summary:

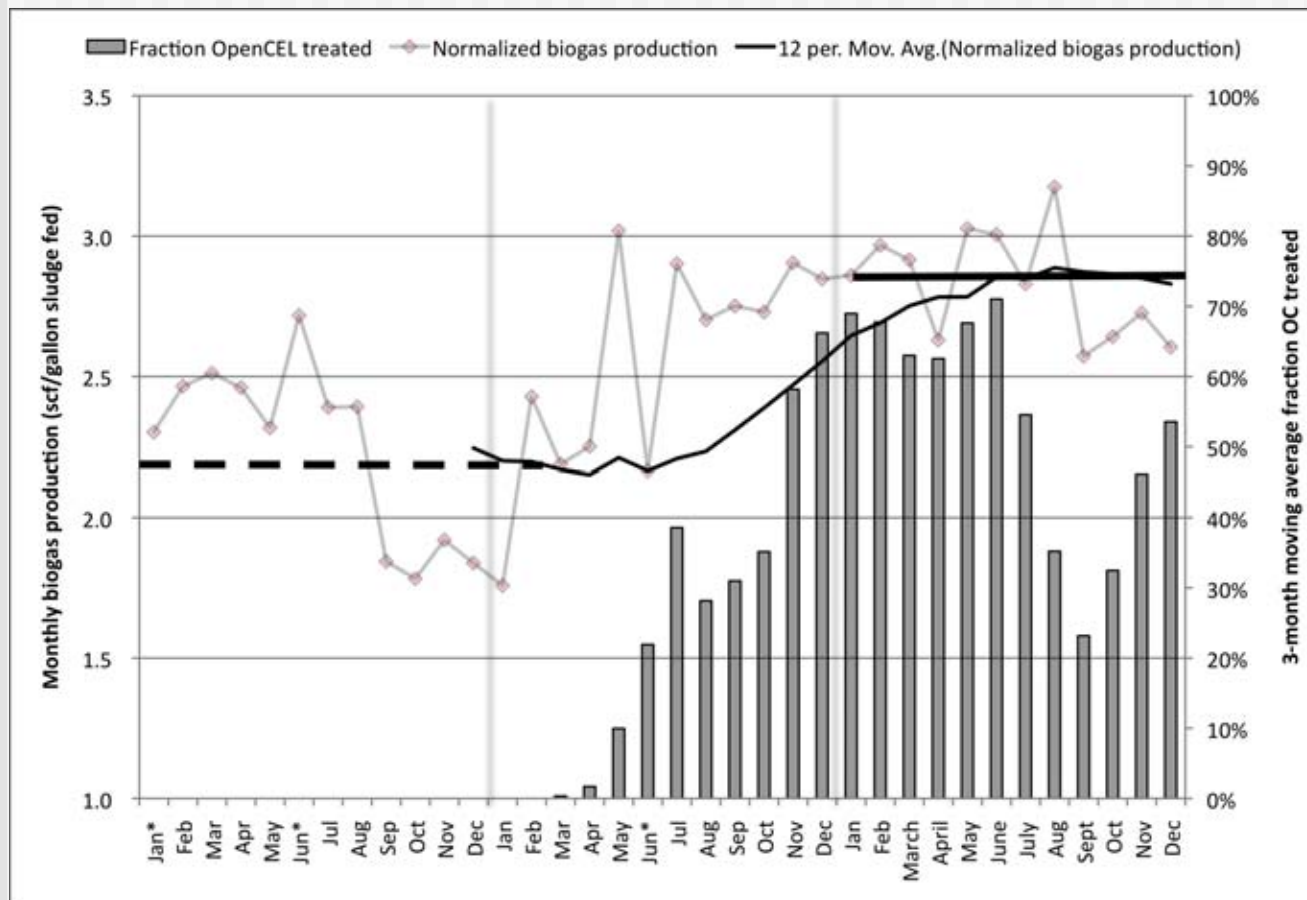
- OpenCEL treatment has increased steadily since startup
- Biosolids trucked from the plant have decreased as more material is treated
- Biogas production has increased in response to additional treatment
- Natural gas consumption for sludge heating has been reduced in the winter months and eliminated in the summer
- In early 2009, FP-treated material has replaced methanol for denitrification and digester performance continues to improve

# Mesa NWWRP 2008 summary results - biosolids



Normalized weight of biosolids trucked from the Mesa NWWRP as compared to a 3-month moving average of the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average 121 tonnes per 1000 m<sup>3</sup> (502 tons/MG); the solid horizontal line represents the 2008 corrected average 100 tonnes per 1000 m<sup>3</sup> (417 tons/MG).

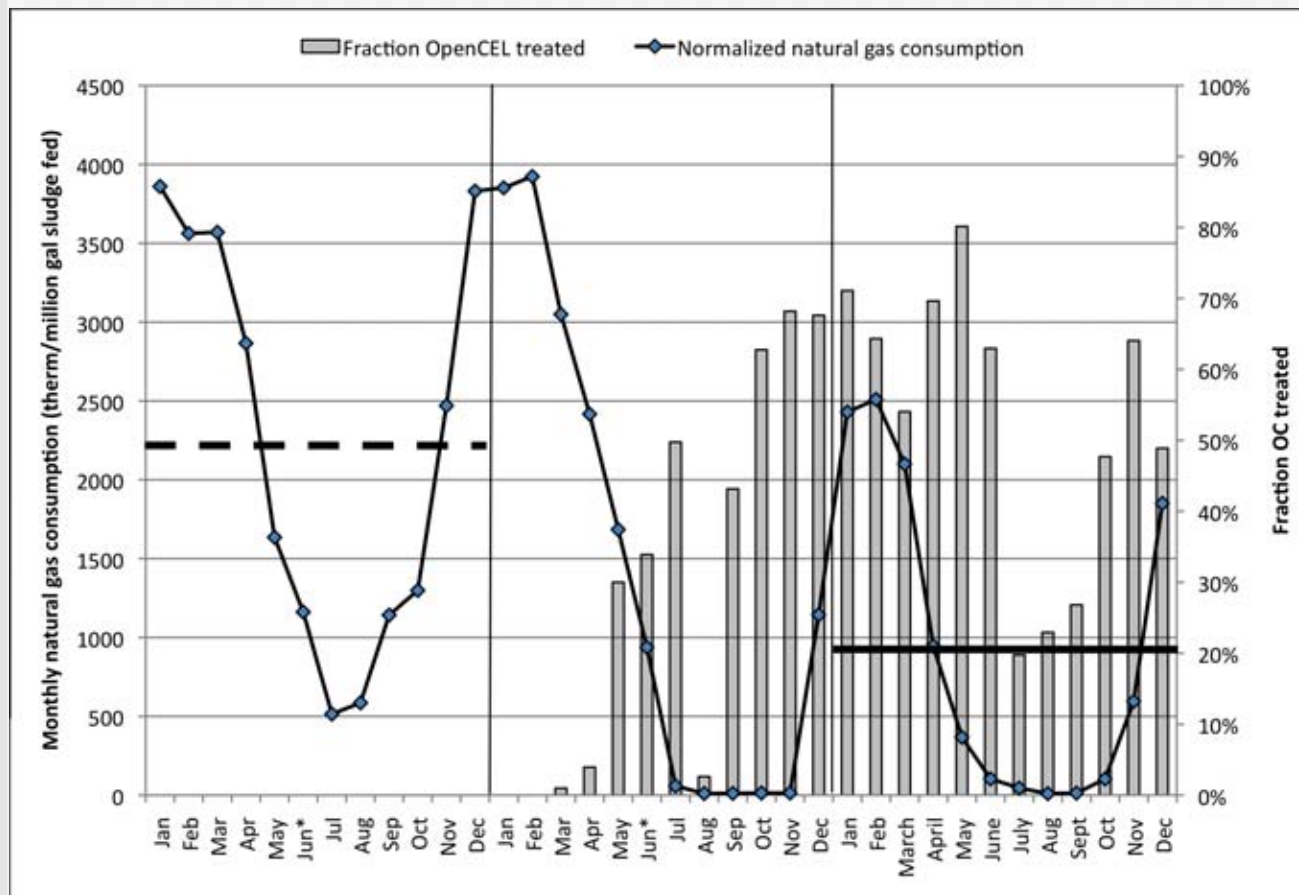
# Mesa NWWRP 2008 summary results - biogas



Normalized biogas generation at the Mesa NWWRP as compared to a 3-month moving average of the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average  $16 \text{ m}^3/\text{m}^3$  (2.14 scf per gallon); the solid horizontal line represents the 2008 average  $21 \text{ m}^3/\text{m}^3$  (2.83 scf per gallon).



# Mesa NWWRP 2008 summary results – natural gas



Normalized natural gas consumption at the Mesa NWWRP as compared to the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average 58,300 BTU/m<sup>3</sup>-month (2,208 therm/MG-month); the solid horizontal line represents the 2008 average 24,400 BTU/m<sup>3</sup>-month (923 therm/MG-month).



## Mesa NWWRP 2008 summary results

### OpenCEL Performance at Mesa Arizona 2008

	Unadjusted	Flow to Digester through OpenCEL Unit	Adjusted to 95% flow
<b>Wet Solids Trucked</b>			
Percent Reduction over baseline	16.8%	52.7%	30.3%
<b>Biogas</b>			
Percent Improvement over baseline	31.9%	52.7%	57.5%
<b>Natural gas consumption</b>			
Percent reduction over baseline	58.2%	N/A	N/A

## Focused Pulsed energy balance

Daily energy production and consumption ratios

		Fraction FP treatment heat recovered					
		0%		50%		100%	
Biogas production increase	80%	Biogas:	31,500 kwh	Biogas:	31,500 kwh	Biogas:	31,500 kwh
		Heat:	0 kwh	Heat:	2,700 kwh	Heat:	5,400 kwh
		Treatment:	(6,100) kwh	Treatment:	(6,100) kwh	Treatment:	(6,100) kwh
			<b>Ratio: 5.2</b>		<b>Ratio: 5.6</b>		<b>Ratio: 6.0</b>
	60%	Biogas:	22,630 kwh	Biogas:	22,630 kwh	Biogas:	22,630 kwh
		Heat:	0 kwh	Heat:	2,700 kwh	Heat:	5,400 kwh
		Treatment:	(6,100) kwh	Treatment:	(6,100) kwh	Treatment:	(6,100) kwh
			<b>Ratio: 3.9</b>		<b>Ratio: 4.3</b>		<b>Ratio: 4.8</b>
	40%	Biogas:	15,750 kwh	Biogas:	15,750 kwh	Biogas:	15,750 kwh
Heat:		0 kwh	Heat:	2,700 kwh	Heat:	5,400 kwh	
Treatment:		(6,100) kwh	Treatment:	(6,100) kwh	Treatment:	(6,100) kwh	
		<b>Ratio: 2.6</b>		<b>Ratio: 3.0</b>		<b>Ratio: 3.5</b>	

Note: Calculation based on treatment of 380 m<sup>3</sup>/day (100,000 gpd) of 5% TS sludge with a 50/50 PS/WAS ratio



## Summary of OpenCEL™ benefits

Benefit	Results to date
Cell opening (release of soluble material)	√√√
Pathogen destruction	√√√
Biosolids heating	√√√
Increased biogas production	√√√
Increased biosolids destruction	√√√
Polymer reduction	√√√
Reduced odors/regrowth/reactivation	√√√
Methanol replacement for denitrification	√√√
Reduction/elimination of CECs	O
Generation of greenhouse gas offsets	√√√
Increased digester capacity	O

Key: “√√√” = Demonstrated benefit; “O” = ongoing investigation