

Improving Energy Balance of Large-Scale Wastewater Treatment Facilities through Co-digestion of Biosolids and High-Strength Industrial Waste: Philadelphia Case Study

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Outline

- Philadelphia wastewater treatment operation
- Wastewater characteristics
 - Aircraft deicing fluid
 - Biosolids from refinery
- Experimental design and methods
- Results and discussion
- Concluding remarks

Philadelphia Water Department Operation

Philadelphia Water Department (PWD) operates three Water Pollution Control Plants to treat approximately 18,925 m³/day (500 MGD) wastewater

1. Northeast Water Pollution Control Plant (NEWPCP)
Typical activated sludge with limited nitrification
2. Southwest Water Pollution Control Plant (SWWPCP)
Activated sludge with pure oxygen, nitrification
3. Southeast Water Pollution Control Plant (SEWPCP)
Typical activated sludge with limited nitrification

PWD Operation: Biosolids management

Three WPCPs generate approximately 8,000 m³/d (2.1 MGD) primary (PS) and waste activated sludge (WAS) that is;

- anaerobically digested
- dewatered in high-speed centrifuges
- historically a small fraction composted in Biosolids Recycling Center (BRC)
 - recently BRC operation has been privatized to Synagro

PWD Operation: Anaerobic digestion

Overall, 20 pancake type digesters, each 7,570 m³ (2 MG) capacity and typically 16-18 digesters operating at any given time

- NEWPCP: 8 digesters
- SWWPCP: 12 digesters

Digester feed:

- 50% PS and 50% DAF thickened WAS by mass
- Typically 4% solids in feed sludge
- Average VS destruction ca 50% (110,000 dry tons VS destroyed per day)

PWD Operation: Anaerobic digestion (Cont.)

62,300 m³ (2.2 million ft³) methane (1 atm and 35°C) generated daily, approximately 1.4 billion BTU energy value

Currently, only a fraction of methane is captured for heat generation and rest is flared

PWD is considering a co-generation facility that would convert 62,300 m³ per day CH₄ into electricity using a 4 MW capacity co-generation plant

Thus, PWD is looking into possibilities to maximize its digestion capacity (through operational improvements) and receiving high-strength industrial wastes for co-digestion and increased CH₄ yield

Waste characteristics

Aircraft deicing fluid (ADF)

Philadelphia Philadelphia International Airport (PHL) uses two different types of propylene glycol-based ADF

- Type I (88% propylene glycol and 11% water and other ingredients such as thickening agents and corrosion inhibitors)
- Type IV (52.2% propylene glycol and 46.8% water and other ingredients such as thickening agents and corrosion inhibitors)

Type I is by far most used ADF at PHL and thus study focused on co-digestion of UCAR™ PG Type I Aircraft Deicing Fluid (Dow Chemical Company) that has 1.38 kg COD per kg ADF

Waste characteristics (Cont.)

Refinery biosolids

Biosolids from activated sludge treatment of oil refinery operations (two different plants, Plant A and B)

Oil-refinery Treatment Plants	TS (mg/L)	VS (mg/L)	COD (mg/L)	BOD (mg/L)
Plant A	15,500	10,600	16,900	1,600
Plant B	26,700	16,900	30,800	2,800

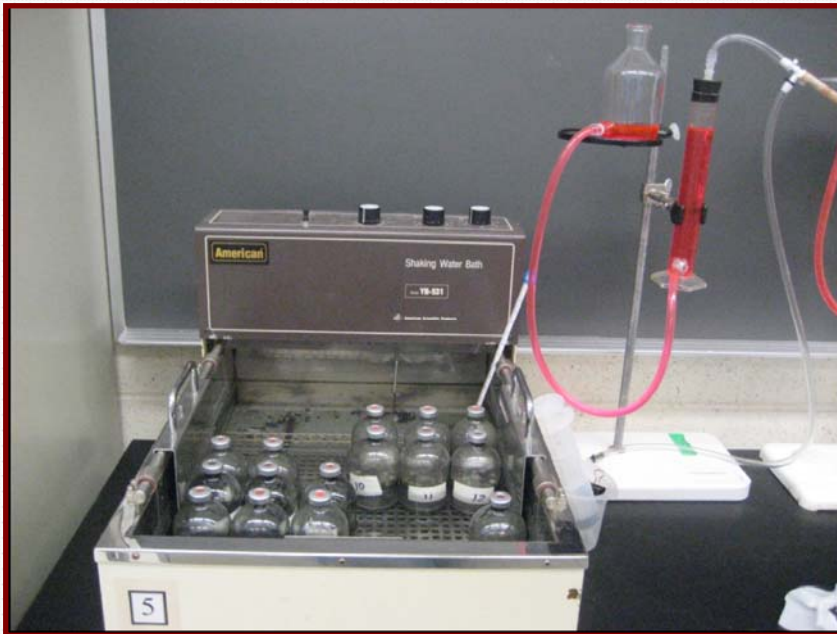
Experimental design and methods

Standard Anaerobic Toxicity Assay (ATA) and Biochemical Methane Potential (BMP) protocols were used

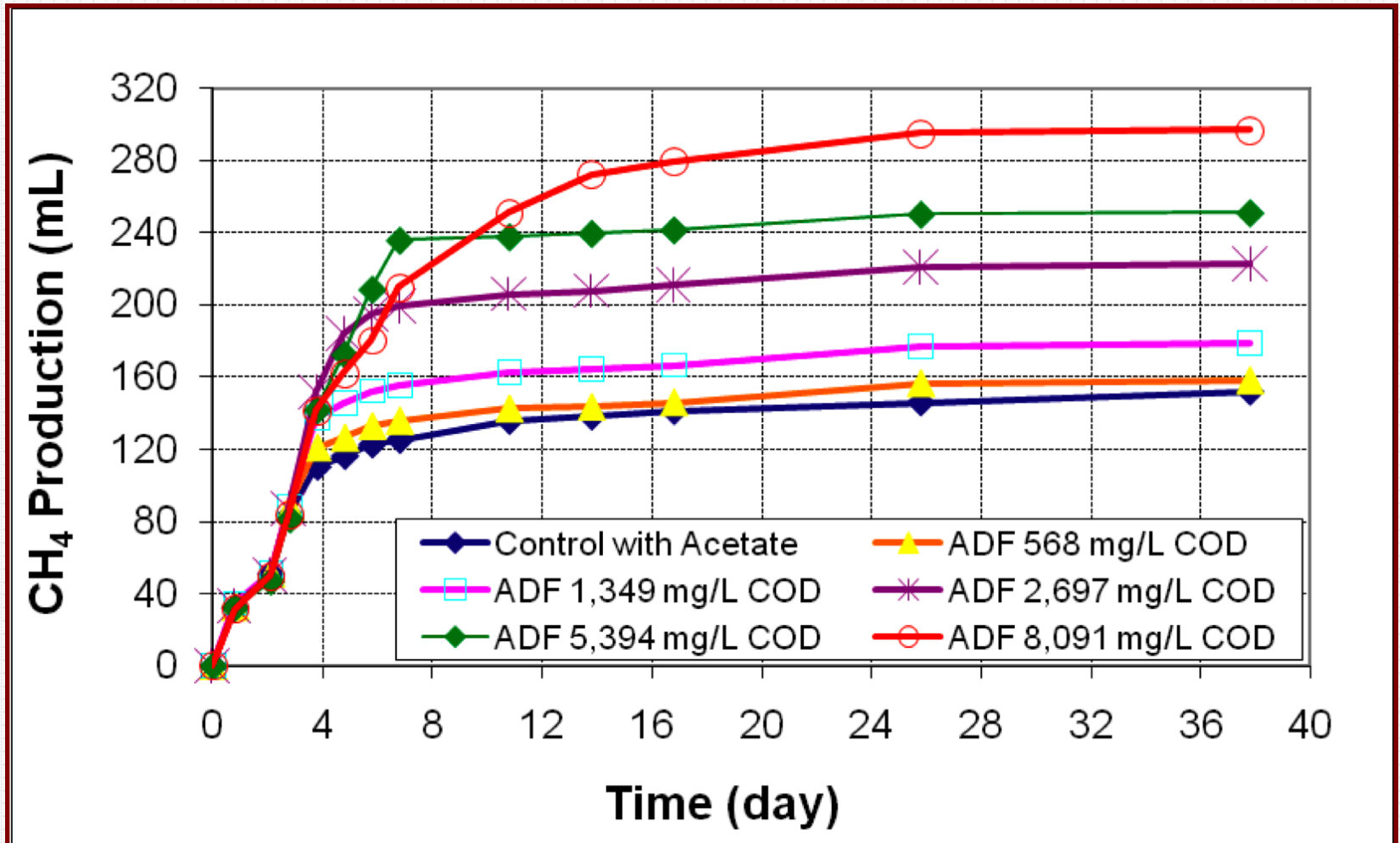
Control 45 mL Seed Sludge 5 mL DI water	Control with Feed Sludge 45 mL Seed Sludge 5 mL Feed sludge	
284 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge	568 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge	1,349 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge
2,679 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge	5,394 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge	8,091 mg/L COD eq. ADF 45 mL Seed Sludge 5 mL Feed sludge

Experimental design and methods (Cont.)

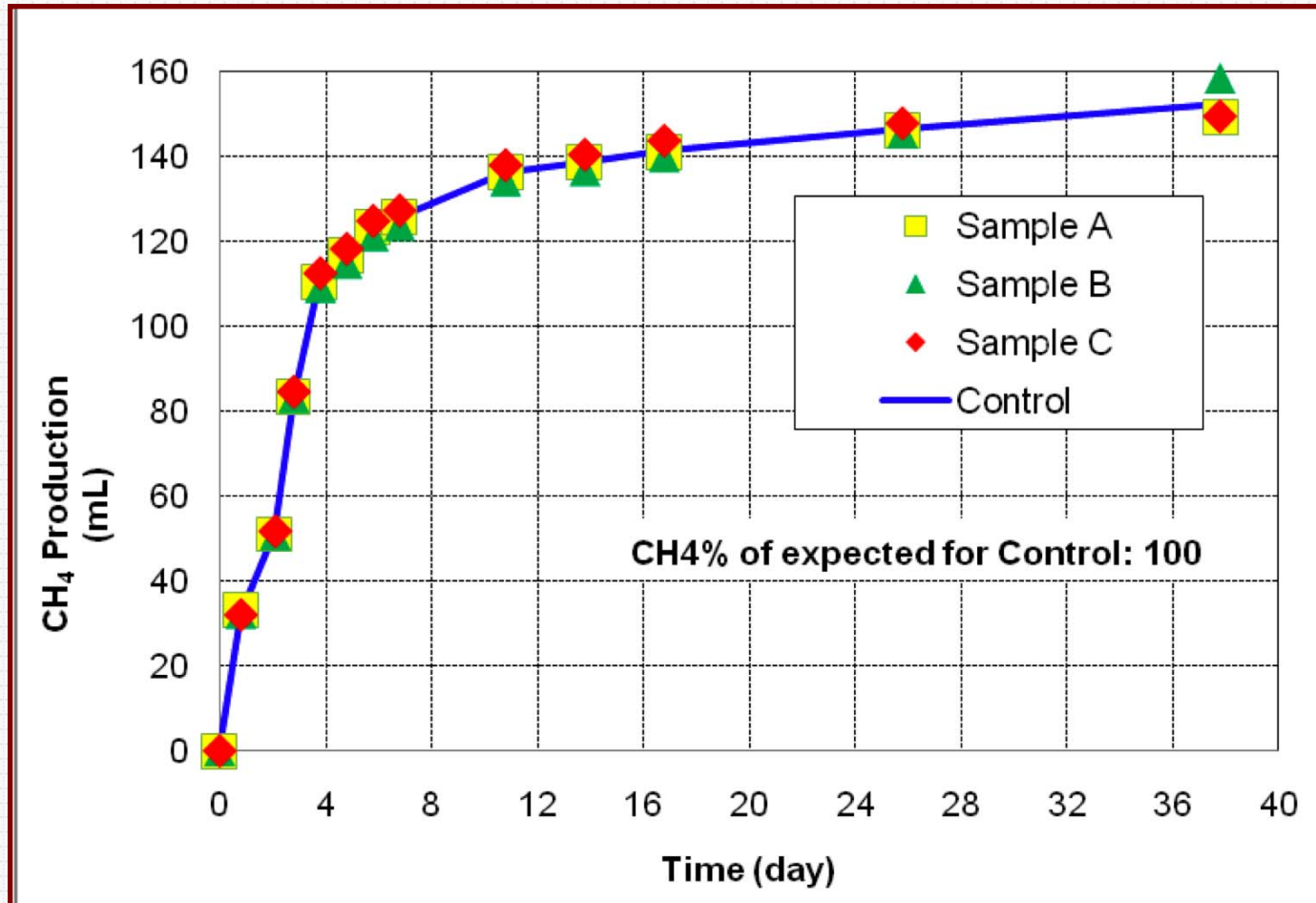
Biogas generation quantified by a simple liquid-displacement device and CH_4 and CO_2 contents of biogas were determined by gas chromatography



Anaerobic toxicity potential of ADF



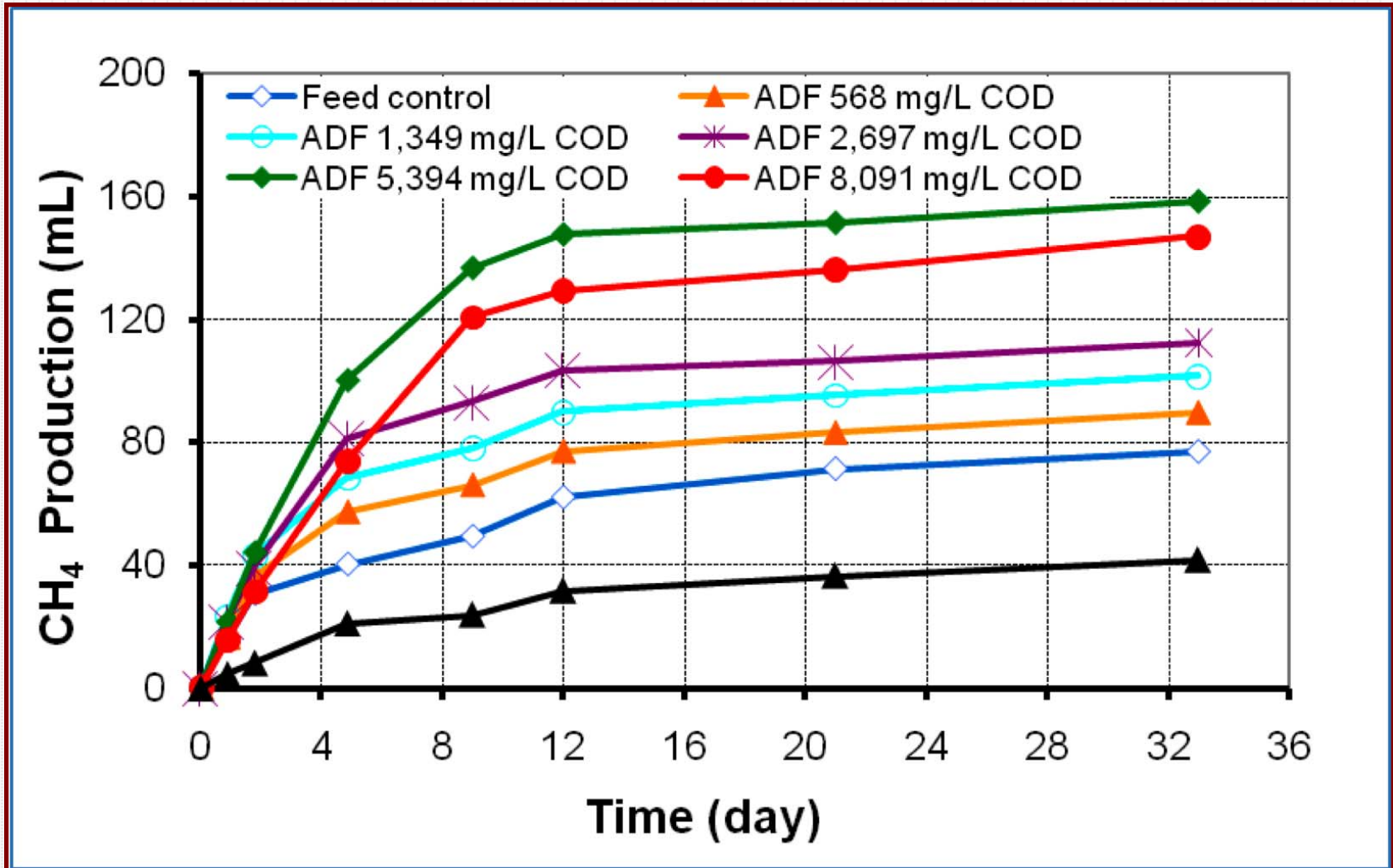
Repeatability of toxicity test



Anaerobic toxicity potential of ADF (Cont.)

COD equivalent ADF Toxicity Study	% CH ₄ of expected			
	5 days	17 days	26 days	38 days
568 mg/L	90	71	139	107
1,349 mg/L	96	93	120	108
2,697 mg/L	76	85	99	92
5,394 mg/L	50	89	94	90
8,091 mg/L	26	89	97	95

BMP of ADF co-digested with biosolids



ADF Co-digestion (Cont.)

COD equivalent ADF Phase - 2	% CH ₄ of expected			
	5 days	12 days	21 days	33 days
568 mg/L	176	153	120	128
1,349 mg/L	121	106	90	93
2,697 mg/L	88	88	75	75
5,394 mg/L	64	90	85	86
8,091 mg/L	24	47	45	50

Refinery biosolids co-digestion

Plant A				
Biosolids fed (mL)	VS fed (mg)	CH ₄ Net production (mL)	Specific CH ₄ production (L CH ₄ /kg VS)	Specific CH ₄ production (ft ³ CH ₄ /lb VS)
15	159	14	88	1.41
30	318	37	116	1.86
55	583	60	103	1.65
Plant B				
Biosolids fed (mL)	VS fed (mg)	CH ₄ Net production (mL)	Specific CH ₄ production (L CH ₄ /kg VS)	Specific CH ₄ production (ft ³ CH ₄ /lb VS)
15	254	40	158	2.53
30	507	79	156	2.50
55	930	153	165	2.64

PWD Operation: Anaerobic digestion (Cont.)

Thus 85% of the ADF could be co-digested, in a single digester, under SRT/HRT of 21 days (retention time for recently cleaned full-scale digesters) at ADF/feed sludge feed of 3.8% (v/v)

Methane potential of ADF is 469 L CH₄/kg ADF or 340 L CH₄/kg COD equivalent of ADF (at 1 atm and 35°C)

Although co-digestible, refinery biosolids has low biochemical methane potential and thus PWD opted not to accept it

Energy potential of ADF co-digestion

PWD received 8 trucks per day loads of ADF runoff from PHL for 2 months during winter of 2009

ADF concentration in runoff was ca 200 g/L

Thus, annual ADF co-digested;

$$\begin{aligned} \text{ADF load} &= \frac{8 \text{ trucks}}{\text{day}} * \frac{28.4 \text{ m}^3}{\text{truck}} * \frac{60 \text{ d}}{\text{year}} * \frac{200 \text{ kg ADF}}{\text{m}^3} * \frac{1.38 \text{ kg COD}}{\text{kg ADF}} \\ &\cong 3.7 * 10^6 \text{ kg COD eq ADF per year} \end{aligned}$$

Effects of PWD's carbon foot-print

Then expected CH₄ generation from ADF co-digestion (at 1 atm and 35°C);

$$\text{CH}_4 \text{ expected} = \frac{0.340 \text{ m}^3}{\text{kg COD}} * \frac{3.7 * 10^6 \text{ kg COD}}{\text{yr}} \cong 1.2 * 10^6 \frac{\text{m}^3}{\text{yr}}$$

Energy potential of ADF co-digestion

$$\text{Energy potential} = \frac{12,000 \text{ BTU}}{\text{kg COD removed}} * \frac{0.85 * 3.7 * 10^6 \text{ kg COD}}{\text{yr}} \cong 38 * 10^9 \frac{\text{BTU}}{\text{yr}}$$

This is over 7% *increase* in overall energy potential of PWD WPCP operations

Energy potential of ADF co-digestion

ADF co-digested means diverting carbon from being decomposed to CO₂ under mostly aerobic conditions

Then 3.15*10⁶ kg COD equivalent of ADF co-digested means 3.15*10⁶ kg COD equivalent CO₂ emission prevented and that is;

$$\text{Reduction in CO}_2 = 3.15 * 10^6 \frac{\text{kg COD}}{\text{yr}} * \frac{44 \text{ kg CO}_2}{64 \text{ kg COD}} * 10^{-3} \frac{\text{ton}}{\text{kg}} = 2,160 \frac{\text{tons CO}_2}{\text{yr}}$$

Considering that CH₄ generated will be used for electricity generation, same amount of CO₂ reduction will be realized due to much less fossil fuels used for electricity generation

Conclusions

It is possible for large wastewater treatment facilities to increase their energy balance and to decrease their carbon foot-print through co-digesting biosolids with industrial wastes

Simple bench-scale tests including ATA, and BMP can be conducted to determine potential toxicity and specific CH_4 potential of any industrial waste and to evaluate cost and benefit of co-digestion

In the case of PWD, BMP test showed 85% of expected methane from ADF could be recovered at 5,394 mg/L COD equivalent ADF in digester feed, equivalent of 3.8% ADF (v/v) in feed

Conclusions (Cont.)

If ADF co-digestion continued, in a single full-scale digester, overall CH₄ yield at PWD facilities would increase by over 7%, an equivalent amount of nearly 10 million kW-h additional energy potential per year, without any modification of the existing process or investment

In addition, ADF co-digestion would reduce carbon-foot print of PHI and PWD by a 4,320 tons decrease in CO₂ emission