Understanding the Opportunities to Successfully Change Effluent from a Cost to a Revenue Stream through Anaerobic Digestion

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Introduction

1. Site Specific Drivers
2. Differences between waste and effluent AD?
3. Impact of Effluent Characteristics
4. Revenue streams
5. Ensuring Project Success
6. Conclusions

1 Site Specific Drivers

Every site is different:

- Corporate sustainability targets i.e. carbon reduction
- Increased production capacity
- Water re-use
- Reduced Utility Bills
- Revenue
- Reduction in trade effluent charges
- Reduced costs/improved reliability of existing on-site treatment
- Improved discharge compliance

These will influence technology choice and the AD system will be required to integrate into existing site assets

2 The Difference between waste & effluent AD

Available Organic Material – Measures as Chemical Oxygen Demand (COD);

2.86 kg COD = 1 m^3 methane

Or 2.86 tonnes COD = 1,000 m^3 methane

Consider minimum organic concentrations & loads to make it economical

Critical factor – what form is this material in???

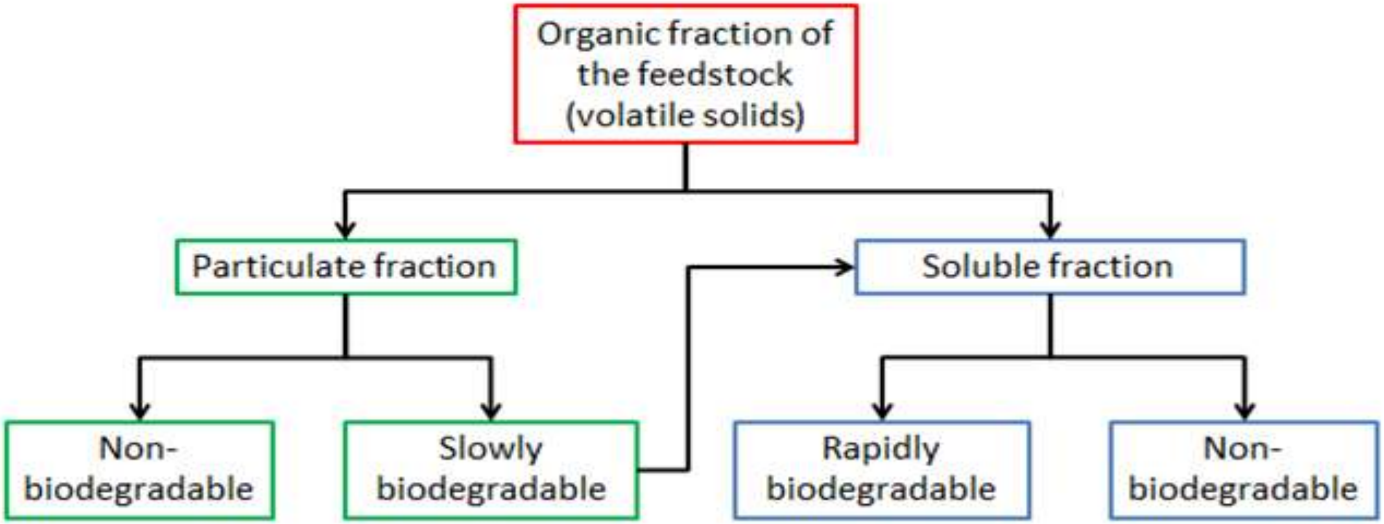
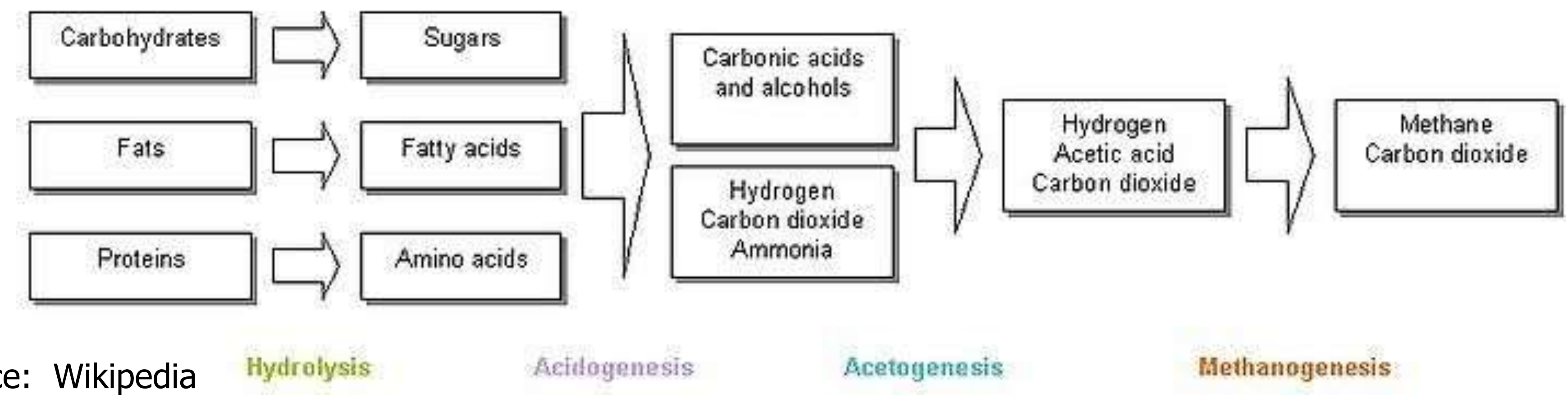


Figure 1: Organic fractions in the digester feed

2 The difference between waste and effluent AD?

Waste Digestion



Source: Wikipedia

Subsequent breakdown or organic material to methane in a completely mixed tank

2 The difference between waste and effluent AD?

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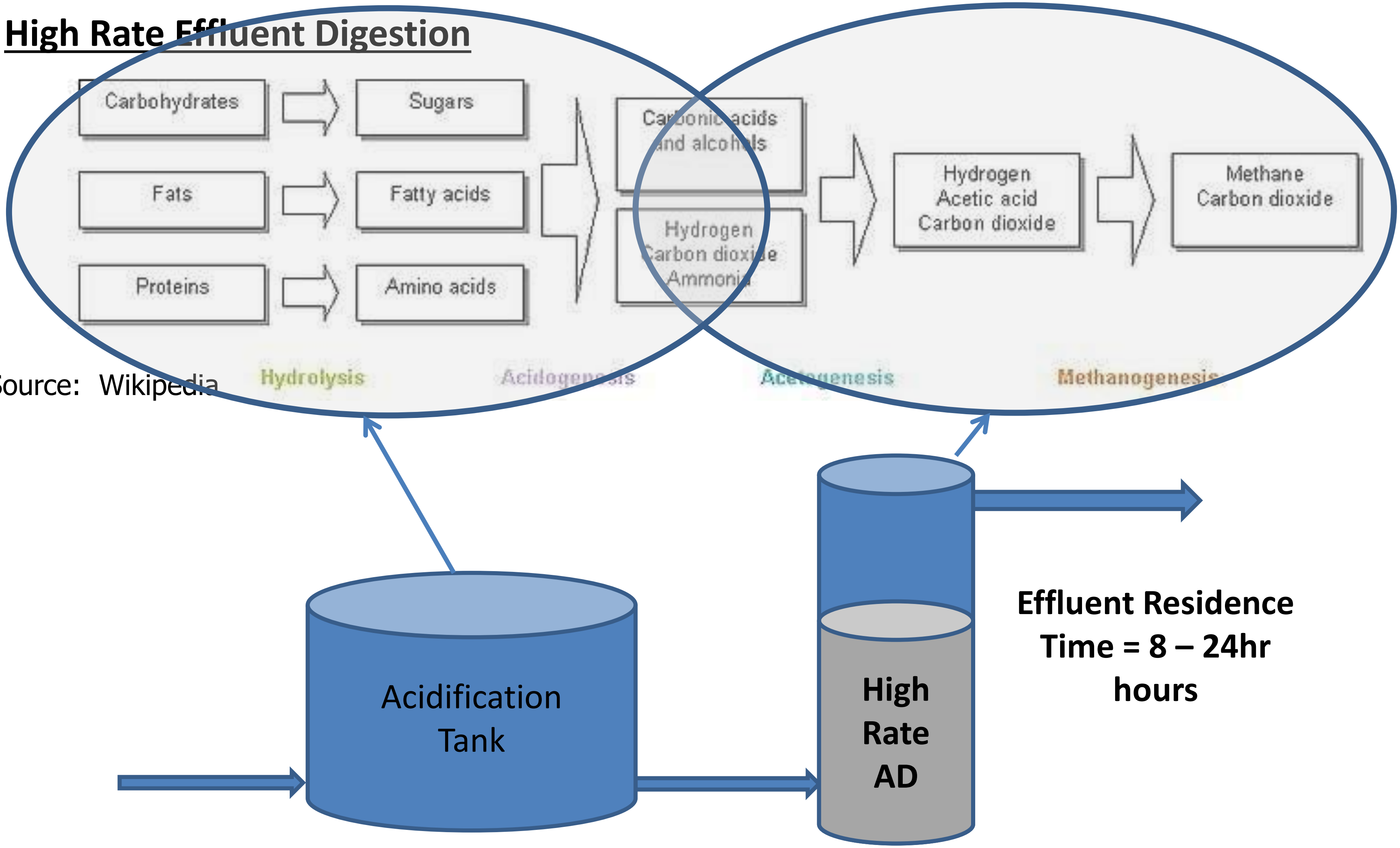
2 The difference between waste and effluent AD?

High Rate Effluent Digestion



Source: Wikipedia

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2 The difference between waste and effluent AD?

Varying designs for different achievable loading rates;

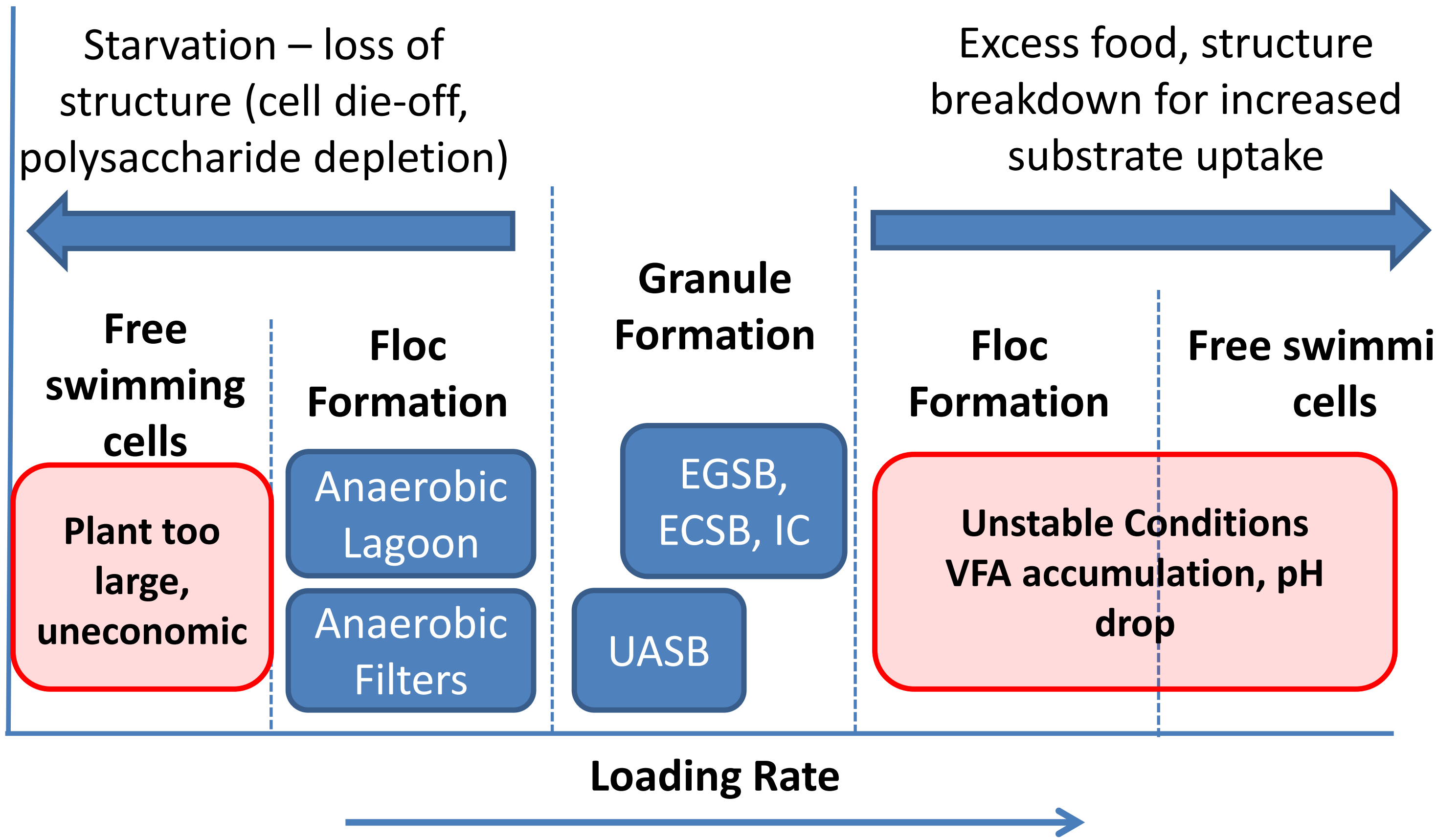
1. **Highest loading rates (10 – 25 kg COD/m^3.d)**
   - **Fluidised granular processes (i.e. EGSB, ECSB, IC)**

2. **Medium Loading rates (5 – 12 kg COD/m^3.d)**
   - **Upflow granular processes (i.e. UASB, UASB-AF hybrid)**

3. **Lower Loading Rates (<5 kg COD/m^3.d)**
   - **Floccular processes (i.e. anaerobic lagoons, CSTR hybrids)**
   - **Fixed film processes (i.e. anaerobic filters)**

New processes configurations / technologies being developed for a range of loading applications

2 The difference between waste and effluent AD?



2 The difference between waste and effluent AD?

AD plants for effluent treatment vary in their design and operation from the processes used for sludge/waste digesters

Due to their small reactor size and efficient operation on soluble organics, granular sludge processes are most widely employed

The effluent is pumped into the base of the reactor under conditions that form a rapid-settling granular sludge with a "caviar" like appearance, whilst treated effluent and biogas is collected from the top of the reactor vessel

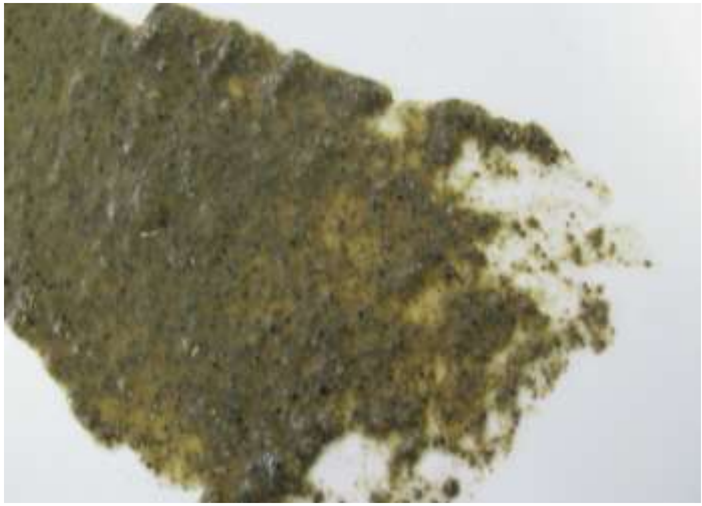
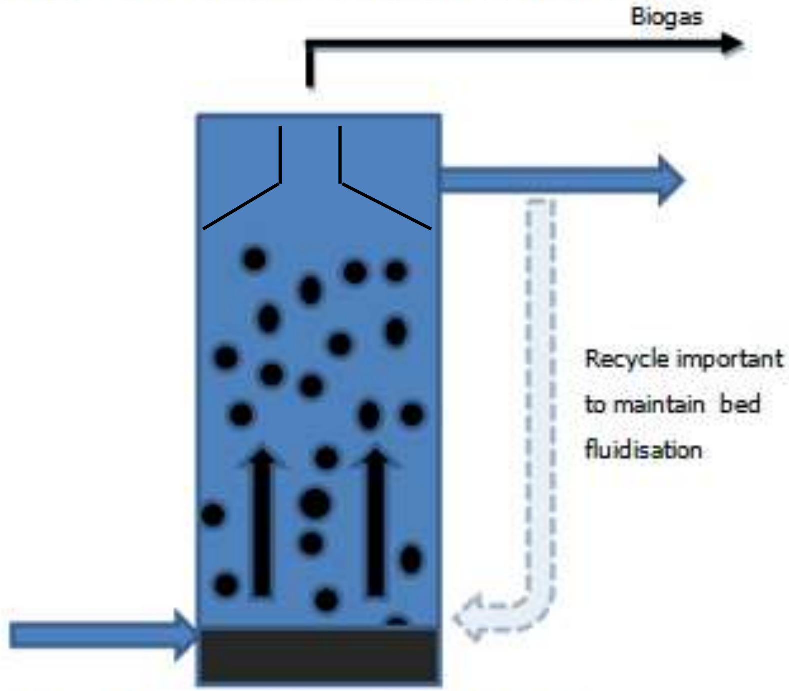


Photo 2: Poor quality stressed biomass sludge

2 The difference between waste and effluent AD?

2. Expanded Granular Sludge Bed (EGSB) Reactor



- Typical loading rates of 5 - 25 kg COD/m^3 reactor volume per day
- High upflow rates to fully fluidise the sludge bed
- Suited to very simple readily biodegradable substrates i.e. brewery, sugar processing, paper mill effluents

2 The difference between waste and effluent AD?

High Rate Effluent Digestion

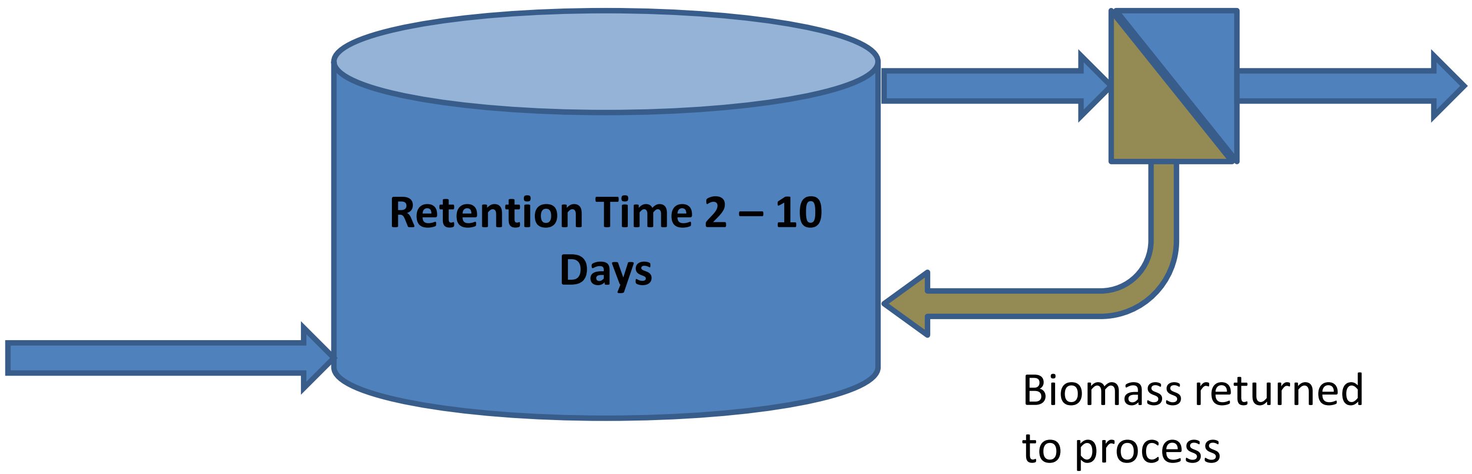
Larger footprint UASB reactors (right)

Compact external circulation reactors (right)

Compact Modular EGSB reactors (left)

2 The difference between waste and effluent AD?

<u>Hybrid Effluent Digestion</u>



Designed to cope with liquid effluent with high solids contents of solids or fats oils and grease i.e. Dairy effluent, distillery vinasse

3 Impact of Effluent Characteristics - Biodegradability

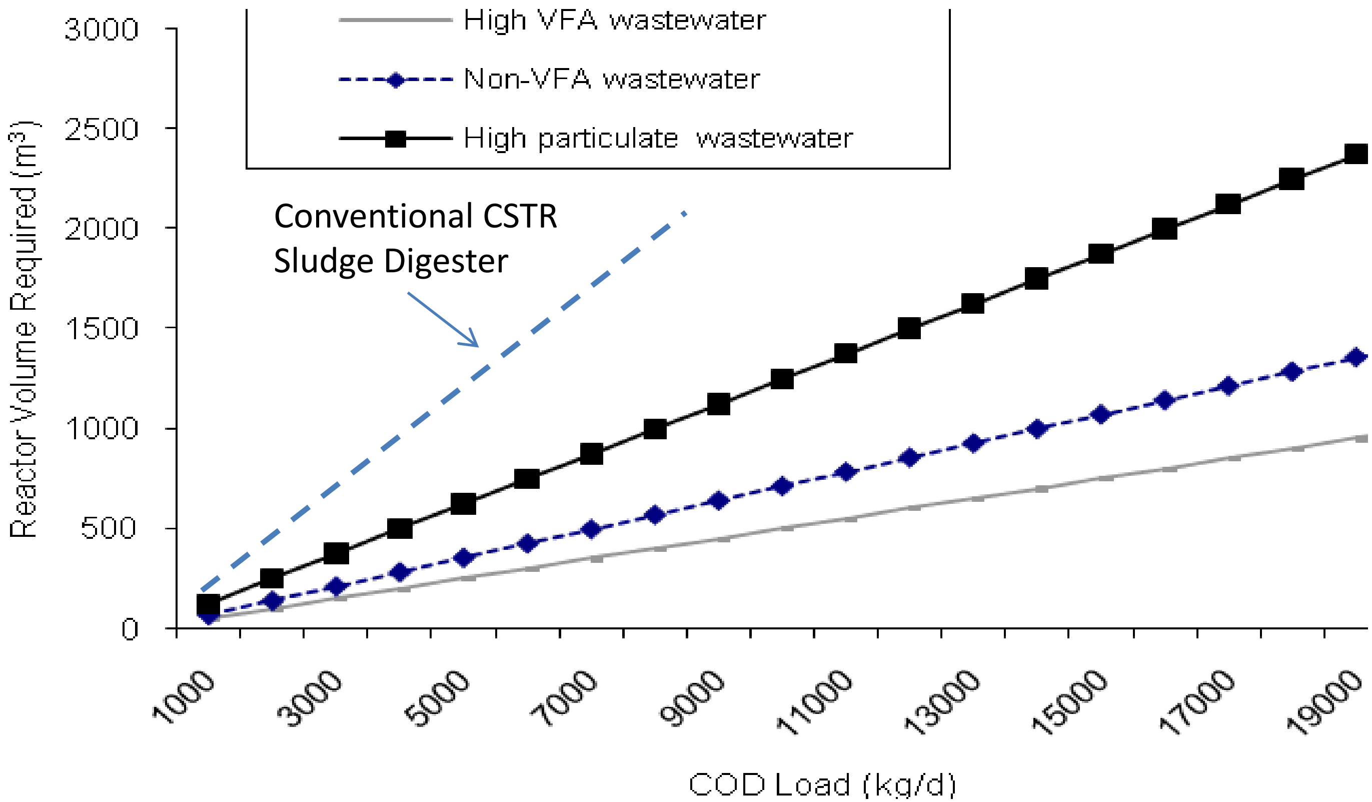


Figure 3: Comparison of reactor volume required for different wastewater types, based upon typical maximum loadings for high VFA, low VFA and high particulate wastewaters of 20, 14 and 8 g COD/l/d respectively.

3 Impact of Effluent Characteristics - Water Temperature

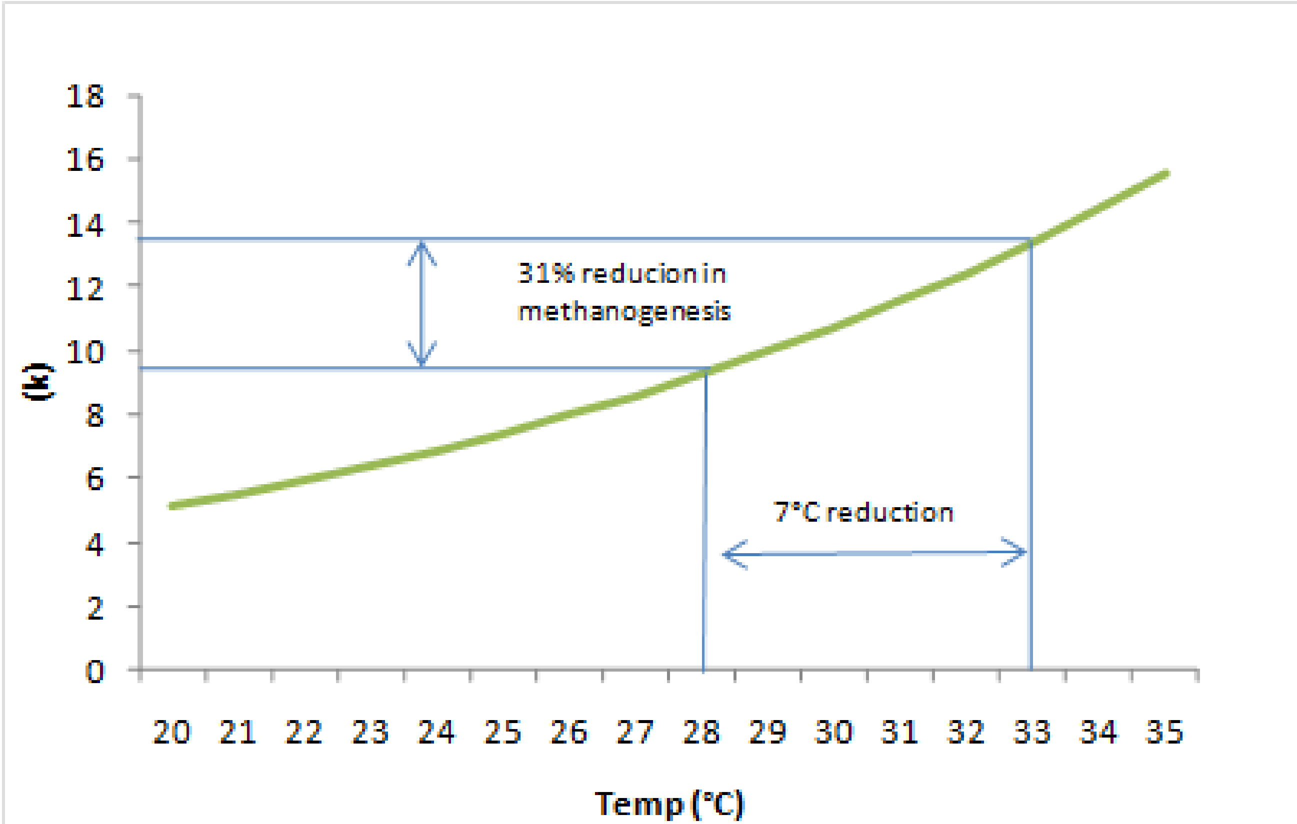


Figure 2: Impact of temperature on the activity of methane producing bacteria

Rule of thumb – removal of 1,000 mg/l of COD produces sufficient gas to increase effluent temperature by 3°C.

3 Impact of Effluent Characteristics - Nutrients

- **Nutrient requirement much lower than for aerobic treatment – COD:N:P ratio of 500:5:1 used as a guide**

- **Micro-nutrients also required**

- **Excess cations can be problematic (i.e. in saline effluent streams)**

Determinand	Recommended mg/kg
Total Phosphorus (P)	15,000
Total Potassium (K)	10,000
Total Magnesium (Mg)	3,000
Total Copper (Cu)	5
Total Zinc (Zn)	50
Total Iron (Fe)	1,500
Total Molybdenum (Mo)	10
Total Manganese (Mn)	20
Total Nickel (Ni)	20
Total Selenium (Se)	1
Total Cobalt	10
Total Boron (B)	10

Salt	50% inhibiting concentration (mg/l)
Mg 2+	1930
Ca 2+	4700
K+	6100
Na+	7600

3 Impact of Effluent Characteristics - Inhibition

- **A range of metals can be inhibitory as well as organic compounds. Anaerobic can be more resistant than aerobic to certain pharmaceutical compounds**

Threshold Concentrations for Inhibitory Metals

Metal	Activated Sludge	Anaerobic Digestion	Nitrification
	Concentration (mg/l)		
Cadmium	10 – 100	0.02	-
Chromium (Cr^{6+})	1 – 10	1 – 50	0.25
Chromium (Cr^{3+})	50	50 – 500	0.05 – 0.5
Copper	1	1 – 10	0.05 – 0.5
Iron	100 – 1,000	5.0	-
Lead	0.1	-	0.5
Magnesium	-	1,000	50
Mercury	10	-	-
Manganese	0.1 – 5.0	1,365	-
Nickel	1.0 – 2.5	2.0	0.25
Silver	5.0	-	-
Zinc	0.08 – 0.5	0.08 - 10	5 - 20

3 Impact of Effluent Characteristics – Fats, oils and grease (FOG)

- High risk to granular processes (granule floation) unless mitigation measures designed in
- Potential to block anaerobic filters and gas / liquid separators

reat i.e. CSTR

Marble sized FOG deposits from an AD plant

4 Revenue Streams

Reduction in Mogden charges or existing treatment plant costs

a) **Example of Mogden Charge Reduction**

- Factory Site produces 1,000 m^3/d effluent containing 250 mg/l solids and 5,000 mg/l COD (365 days per year)
- AD process removed 90% of the COD (solids remain unchanged)
- Annual Mogden charge reduces from around £950k to £300k giving an annual saving of £650k!

b) **Existing Biological Treatment**

Savings likely to be less than Mogden and will depend upon the specific processes used but likely to include;

- Reduced aeration / oxygen costs
- Reduction in chemical consumption (pH correction, nutrients, polymer)
- Reduced sludge handling and off-site disposal/recycling costs

4 Revenue Streams

Value of the Biogas

Typically used in CHP or site boilers to reduce site utility bills and claim the Feed in Tariff (FIT) or Renewable Heat Incentive (RHI) although gas-to-grid and use in vehicles becoming more common.

Feed in Tariff

All renewable power generated by AD eligible plus the additional benefit of displaced electricity cost OR export tariff for export to grid.

Feed in Tariff Rates

Energy Source	Scale	Type / Rate	Tariff (p/kWh)	
			< 30/9/14	> 1/10/14
Anaerobic digestion	≤250kW		12.46	11.21
Anaerobic digestion	>250kW - 500kW		11.52	10.37
Anaerobic digestion	>500kW		9.49	9.02

Source: http://www.fitariffs.co.uk/eligible/levels/

4 Revenue Streams

Value of the Biogas

Renewable Heat Incentive

Claimed for heat utilised from CHP, direct combustion or injection of bio-methane to grid (p kWh shown below)

Biomethane injection	Biomethane	biomethane all capacities	7.5
Small biogas combustion	Biogas combustion	Less than 200 kWth	7.5
Medium biogas combustion (commissioned on or after 4 December 2013)		200 kWth and above & less than 600 kWth	5.9
Large biogas combustion (commissioned on or after 4 December 2013)		600 kWth and above	2.2

Source: www.ofgem.gov.uk

4 Revenue Streams

Example of Revenue

For the previous example for a factory site producing 1,000 m^3/d effluent containing 250 mg/l solids and 5,000 mg/l COD with 90% COD removal (365 days per year) and use of biogas in CHP;

- Plant produces ~1,500 m^3 methane per day
- CHP 38% efficiency produces 237 kW output
- CHP 25% efficiency high grade heat utilised on site
- Electricity and natural gas displaced at 7p kWh and 2.5p kWh respectively
- Value of power produced (FIT & Saving) = £379k per annum
- Value of heat produced (RHI & Saving) = £52k per annum

Total Revenue from Biogas = £431k per annum

Total from Revenue from Biogas and Mogden Saving = £1.08M per annum

5 Ensuring Project Success – Process Trials to Mitigate Risk

- Is the influent treatable?
- Will the process be compliant?
- Will the project deliver the expected return on investment?
- How robust is the process?
- How will this integrate into existing assets?

Independent Process Trials are the Key to Project Success!

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5 Ensuring Project Success - Process Trials to Mitigate Risk

Anaerobic Digestion modelling (top left); Biodegradability testing (above); Site based pilot trials (bottom left)

5 Conclusions

- AD has great potential to reduce site costs and produce revenue and is currently supported by a range of government incentives
- To ensure a project is successful it must be aligned with the sites drivers and a holistic approach taken to optimise its integration into existing assets
- The effluent composition and variability must be understood to select the most appropriate technology and ensure it is designed correctly
- Pilot trials and testing ensures that the full scale process will perform in line with expectations and that the full benefits are realised through optimum design and performance

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