UK Case Study & Sludge Processing Methods

Stephen Riches (MIMechE)
Asset Planning Process Manager (Bio-Resources)

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Contents

• Overview of Anglian Water
• Biosolids recycling to agriculture in the UK
  • Regulatory Framework
  • Sludge use in Agriculture Regulations
  • Safe sludge matrix
  • Biosolids assurance scheme (BAS)
• Treatment Technologies
  • Conventional treatment systems
  • Enhanced digestion systems
• Overview of our strategy
  • Our advanced digestion technologies
Anglian Water

- We serve 6 million domestic customers
- Supply 1.2 billion litres of water per day
- Collect 927 million litres of waste water for recycling at 1128 centres
- Treat 150,000 tonnes dry solids (TDS) per annum of sewage sludge producing 400,000 wet tonnes of biosolids product for recycling to agriculture as a soil conditioner
- Generate 100GWh per annum of renewable electricity from sewage sludge biogas
Water 2020 Bio-Resource Price Control

Scope of assets and activities covers as per diagram below

Raw Sewage

1,130 WRCs

Exported to Grid

Used by 10 integrated WRCs / STCs

13 Sludge Thickening Centres

10 STCs

Electricity

CHP Engines

<10% DS

>10% DS ~ 70% sludge

Dewatered digestate marketed to farming community

<10% DS ~ 30% sludge

Return Liquors

10 WRCs
ANGLIAN WATER CARBON STORY

2006 CHALLENGES
CLIMATE CHANGE & POPULATION GROWTH

2006 RESPONSE
Energy Initiative launched promoting action in energy efficiency.

2007 STRATEGY
Measurement and Baselining Capital and operational carbon for the 2010-2015 business plan.

2008
Anglian Water takes leaders from its supply chain to the MayDay Summit - Action Pledged.

2009
Water Innovation Network Launched Challenging SMEs in response to the carbon challenge.

2010

TARGETS
Back to back with the supply chain. £2 billion programme.

Deliver a 50% reduction in capital (embodied) carbon by 2015 from a 2010 baseline

Exceed a 10% reduction in real terms in gross operational carbon by 2015 from a 2010 baseline

2010 TARGETS DELIVERED
• Exceeded 10% reduction in operational carbon in real terms
• 54% reduction in capital carbon

PAS2080
Carbon management in infrastructure. Anglian Water the first company to be verified globally. Next step PAS to ISO.

INNOVATION
Through zero cement concrete, 60% carbon reduction in the base slab.

EXEMPLARY PROJECT
• Saved 7,302t CO2e
• Saved £1.6m
This project brought together the learning of the past five years. From early design collaboration with operations and the supply chain, to using innovative materials, off site build and zero material removed from site, faster delivery and zero accidents.

2011
Bedford Water Recycling Centre

2012
SUCCESS
Aligning the Supply Chain
• 66% reduction in capital carbon
• 170% reduction in operational carbon
• 43% reduction in capital costs

2013

REDUCE CARBON REDUCE COST
Awards - Promoting positive behaviour in our supply chain

2014

UPDATED TARGETS
Deliver a 50% reduction in capital (embodied) carbon by 2020 from a 2010 baseline

Exceed a 7% reduction in real terms in gross operational carbon by 2020 from a 2015 baseline

2015

2016

NEW TARGET
CARBON NEUTRALITY BY 2050

2017

2018

GOVERNANCE
Capital and operational carbon challenged against baseline prior to construction.

SUPPLY CHAIN
Collaboration and engagement in meeting the carbon challenge.

ICE Treasury Infrastructure Carbon Review
Aimed at leaders to deliver carbon and cost reduction. Through the Green Construction Board, Anglian Water at the heart of this document.
Biosolids Recycling
recent history

- Sewage sludge directive 1996
- Safe sludge in Agriculture Regulation (1989)
- Introduction of ‘safe sludge matrix’ in 1998 was catalyst of new wave of technology development. Incentive for renewable fuels and electricity from 2000 has further boosted development
- DEFRA Code of Practice introduced in 1996
- Biosolids Assurance Scheme (BAS) introduced in 2016
- OFWAT Water 2020 – Bioresource Markets
Safe Sludge Matrix

- Code agreed between WASC’s and British Retail Consortium in 1998
- Introduces two treatment standard
  - Conventional
  - Enhanced
- Matrix sets out use of biosolids based on crop type and rotation
# Safe Sludge Matrix

## The Safe Sludge Matrix

<table>
<thead>
<tr>
<th>CROP GROUP</th>
<th>UNTREATED SLUDGES</th>
<th>CONVENTIONALLY TREATED SLUDGES</th>
<th>ENHANCED TREATED SLUDGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRUIT</strong></td>
<td>√</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td><strong>SALADS</strong></td>
<td>√</td>
<td>(30 month harvest interval applies)</td>
<td>✓</td>
</tr>
<tr>
<td><strong>VEGETABLES</strong></td>
<td>√</td>
<td>(12 month harvest interval applies)</td>
<td>✓</td>
</tr>
<tr>
<td><strong>HORTICULTURE</strong></td>
<td>√</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>COMBINABLE &amp; ANIMAL FEED CROPS</strong></td>
<td>√</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>- GRAZED</strong></td>
<td>√</td>
<td>(Deep injected or ploughed down only)</td>
<td>✓</td>
</tr>
<tr>
<td><strong>- HARVESTED</strong></td>
<td>√</td>
<td>(No grazing in season of application)</td>
<td>✓</td>
</tr>
</tbody>
</table>

**NOTE:** ✓ All applications must comply with the Sludge (Use in Agriculture) Regulations and DETR Code of Practice for Agricultural Use of Sewage Sludge (to be revised during 2001). ✗ Applications not allowed (except where stated conditions apply).
End Product Standards

Conventional Standard
- 2 log reduction in indicator pathogen E.coli 0157

Enhanced Standard
- 6 log reduction in indicator pathogen E.coli 0157
- Absence of salmonella

HACCP (Hazard Analysis Critical Control Points) applied to treatment process. Examples, set process hold time above a minimum temperature or minimum dose rate of lime per tonne treated with pH monitoring.
Currently 11 WaSCs united in ambition to maintain confidence in biosolids recycling by adopting best practice (BAS) – also creates a *level playing field*

Post Water 2020 there could be say 100 companies handling sludge containing materials – a very different & commercialised market?
Maintaining Confidence

Must demonstrate biosolids are beneficial to agriculture and the environment as a whole

That it is a safe and sustainable practice

That they are a valuable resource

Must maintain support from food chain stakeholders

Must have Government support

and a clear regulatory framework which supports biosolids use as a resource rather than waste
Various treatment technologies used to produce biosolids

73% output treated by AD with advanced AD treatments gradually replacing lime treatment and conventional AD

Higher quality products reduce the potential for odour nuisance

Odour probably has the greatest impact on public perceptions

So odour control is directly linked to maintaining confidence
Recycling to agriculture

3.6 million tonnes per annum biosolids are recycled to agricultural land

Applied to 146,000 hectares/annum

Biosolids product is mainly cake at 20 – 25% dry solids

It can be safely & securely stored in field heaps before spreading & incorporation

There are very few problems and the current systems work well
Recycling to agriculture

Aligns with UK the Government recycling strategy and the EC Circular Economy

**Nutrient value** to UK agriculture £25m/annum - mainly Phosphate (4.5%) and Nitrogen (4.0%) plus Sulphur, Potash and Magnesium

**Strong demand** from farmers – it is worth £170/hectare in nutrients alone

Anglian Water sell it as **nutri-bio** for £2.8m/annum - reduces customer water bills

**Biosolids** - a resource with considerable value!
Benefits to soils & environment

Improved soil structure
Increased water retention capability
Increased life in soil (from microbes to earthworms)

These lead to.............

.... Less soil work and energy required
.... Increased crop yields & reduced risk of yield loss
.... Maintaining soil structure and nutrient levels
.... Reduced risk of diffuse pollution
.... A natural provision of nutrients &
.... Greenhouse gas reductions

It will be essential to maintain the benefits to soil & the environment.
Sustainable, safe recycling

Product testing for microbiological parameters, elements and nutrients.

Soil analysis for elements and nutrients.

Safe Sludge Matrix (since 2001) defines treatment standards and minimum periods between application and harvest/grazing.

HACCP principles for treatment processes.

The Water Industry is consolidating this into the Biosolids Assurance Scheme.

To provide increased transparency and reassurance to food chain stakeholders
Biosolids Assurance Scheme

Water Industry initiative to provide reassurance to the food chain and consumers.

Brings together regulations and best practice into a single transparent Standard.

Sets a minimum Standard – protects the environment & creates a level playing field for all, whilst facilitating sludge trading.

Stakeholder input and support are essential to maintain validity and credibility.

Third party audit by NSF Certification

Aspiration for UKAS Accreditation

Commitment from Water UK Board to achieve 100% BAS compliance
Treatment Technologies

Conventional

- Lime Stabilisation
- Convention anaerobic digestion and liquid batch storage (21 days)
- Conventional anaerobic digestion and cake storage (3 months)
- 2 stage digestion (acid phase + conventional anaerobic digestion)

Enhanced

- Pasteurisation (70°C for minimum 30 mins) and digestion
- Biological hydrolysis with pasteurisation and digestion
- Thermal hydrolysis and digestion
- Thermal drying of raw or digested sludge
Typical Conventional AD System

HACCP Control for this system: Min digester HRT 12 days at >33C & min 21 day secondary batch storage
Advanced Digestion Systems

- Conventional digestion is a four stage biological process
- Separation of stages 1-3 by biological or thermal hydrolysis improves the overall conversion efficiency by removing competing bacteria from the digestion phase
- Pre-treatment also allows for the sludge to be pasteurised to achieve an enhanced treated biosolids product
Why Advanced Anaerobic Digestion?

• Can Produce both ‘Conventional and Enhanced Treated’ products suitable for recycling to agricultural land as a soil conditioner which provides a wider range of outlets as set out in the safe sludge matrix

• Higher levels of product acceptability, lower odours

• Higher conversion of organic matter, minimising quantity of product whilst maximising biogas yields

• Biogas utilised to produce heat and electricity using combined heat and power engines

• Reduced operating cost, maximised renewable energy production and reduced risk
Our Bio-resource Strategy

• Our strategy is to treat all sludge to the higher enhanced treated standard by 2020, minimising risks to agricultural outlets and reducing the volume of solids to be recycled

• Product recycled to agriculture as a soil conditioner providing valuable nutrients and organic matter to farmland

• Biosolids Quality Assurance Scheme (BAS) was introduced in 2015. Industry wide system, development was led by water companies and consulted key stakeholders from agriculture and the food processing industries. Objective applying an auditable quality standard for all biosolids recycled to agriculture

• Enhanced Digestion technology was a clear winner compared with alternatives as provides maximum solids destruction and reliably achieves enhanced treated quality

• Maximising solids destruction increases biogas yields and improves business case for renewable power generation and supports our wider renewable energy and carbon goals
Bio-Resources Treatment

Typical Flow sheet used in Anglian Water

Indigenous Sludge
Primary 1-3%DS
SAS 4-6%DS

Cake Imports
Up to 300 m3/d
20-35%DS range

Input Energy
733GWh

Screening

Blending

Hydrolysis & Pasteurisation
(Biological or Thermal)

Anaerobic Digestion

CHP Engines

Energy in Biogas
328GWh to 410GWh

124 – 156 GWhe

Advanced Digestion Facility

10 Treatment Centres
• 2no CAMBI Thermal Hydrolysis
• 3no Suez (Monsal) Enzymic Hydrolysis
• 4no AWS HpH Biological Hydrolysis
• 1no Pasteurisation plant

Best performing plants achieving conversion rate >1MWh/tds

Dewatering

Treated biosolids for use in agriculture

Liquid Imports
Up to 1200m3/d
1-8%DS range

Screening to landfill

Cake Imports
Up to 300 m3/d
20-35%DS range

Ingestion Tanks

Screening

Input Energy
733GWh

Blending

Hydrolysis & Pasteurisation
(Biological or Thermal)

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Dewatering

Treated biosolids for use in agriculture

Typical Flow sheet used in Anglian Water
Advanced Digestion Technologies used in Anglian Water

Cambi Thermal Hydrolysis

Cottonvalley (Milton Keynes)
- Commissioned 2008
- 20,600 tonnes dry solids per annum capacity
- 1.75MWe + 0.65KWe CHP engines

Whitlingham (Norwich)
- Commissioned 2010
- 20,800 tonnes dry solids per annum capacity
- 1.75MWe + 1.2MWe CHP engines
- Sharon Liquor treatment plant
Thermal Hydrolysis

- Raw feed sludge
- Pulper
- Reactor x 4
- Flash Tank
- Heat Exchanger
- Dilution water
- Pre-treated sludge to Mesophilic Anaerobic Digesters

- Total retention time ~ 4.5 hrs
- DS of raw sludge ~ 16 w/w%
- DS of digester feed ~ 10.5 w/w%

HACCP control: Min reactor pressure 4 bar, min time 24 mins
Advanced Digestion Technologies used in Anglian Water

Suez Enhanced Enzymic Hydrolysis (EEH)

Cambridge
- Commissioned in 2007
- 0.6MWe + 0.34MWe CHP engines
- 10,200 tonnes dry solids per annum capacity

Kings Lynn
- Commissioned in 2008
- First EEH plant to use steam heating
- 19,000 tonnes dry solids per annum capacity
- 2no. 1MWe CHP engines

Gt Billing (Northampton)
- Commissioned in 2010
- Largest STC operated by Anglian Water
- 36,500 tonnes dry solid per annum capacity
- 3no. 1.4MWe + 1.5MWe CHP engines
Suez EEH Process

HACCP control: Min stage 2 temp 55C, min hold time 5 hours
Advanced Digestion Technologies

Anglian Water - HpH Process

- New process developed by AWS and partners
- Patent awarded in July ‘16
- Biological hydrolysis process
  - Basildon 2013
    - 10,100 tonnes dry solids capacity
    - 2no. 0.6MWe CHP engines
    - AMTREAT Liquor Treatment
  - Cliff Quay (Ipswich) 2013
    - 14,800 tonnes dry solids capacity
    - 2no. 1.2MWe CHP engines
    - AMTREAT Liquor Treatment Plant
  - Colchester 2014
    - 14,900 tonnes dry solids capacity
    - 2no. 1.2MWe CHP engines
    - AMTREAT Liquor Treatment Plant
  - Pyewipe (Grimsby) 2014
    - 16,667 tonnes dry solids capacity
    - 2no. 1.2MWe CHP engines
The HpH Process in Detail

- Hydrolysis tank
- Digester feed pumps
- Steam injectors
- Rotary lobe recirculation pumps
- Radar device
- Pasteurisation tanks
- PRV/anti vacuum
- Heating Tank
- Heat exchanger
- Hot water
- Tanks - GCS with SS316 roofs and top rings
**HpH Biological Hydrolysis**

Thickened sludge feed to HpH (8%DS) → Heating tank 42°C → Pasteurisation tank No.1 55°C min 5hrs hold → Pasteurisation tank No.2 55°C min 5hrs hold → Hydrolysis tank 38-42°C 1-2 days → Feed to mesophilic anaerobic digesters

- **Heat Ex**
  - Recovered heat (hot water) from CHP Engines
  - Steam from composite steam raising boilers, recovers heat from engine exhaust

- **Cooling**

**HACCP control:** Min stage 2 temp 55°C, min hold time 5 hours
Our Biogas CHP Sites

CHP Fleet

Pyewipe
2No. 1.2MWe MWM
Kings Lynn
2No. 1MWe Jenbacher
Great Billing
3No. 1.4MWe Jenbacher + 1No. 1.5MWe MWM
Cottonvalley
1No. 1.75MWe Cummins + 1No. 0.65MWe CAT
Whitlingham
1No. 1.75MWe Cummins + 1No. 1.2MWe MWM
Cambridge
1No. 0.6MWe MWM + 0.34MWe MAN
Cliff Quay
2No. 1.2MWe MWM
Colchester
2No. 1.2MWe MWM
Chelmsford
2No. 0.37MWe Perkins
Basildon
2No. 0.6MWe MWM
Renewable Generation

CHP Power (GWh)

- Conventional AD & CHP
- Advanced AD
- Gt Billing
- HpH
- O&M brought in-house

Year:
- 2005-06
- 2006-07
- 2007-08
- 2008-09
- 2009-10
- 2010-11
- 2011-12
- 2012-13
- 2013-14
- 2014-15
- 2015-16
- 2016-17
Plant Performance

- Use conversion rate, gross power generated per tonne dry solids of raw sludge treated (MWh/tds) as key performance measure.

- Our top five sites have averaged a conversion rate of 1.05MWh/tds which is industry leading performance.

- Best performing sites use biological hydrolysis technology (4No. HpH & Great Billing EEH).

- Targeting interventions to improve conversion rates on other sites.

- Objective to get all sites operating consistently above 0.8MWh/tds.
Summary

• Bio-resource strategy is to move towards treating all of our raw sludge production to an enhanced treated standard by advanced digestion whilst maximising the generation of renewable power from the biogas produced

• 98.4GWh was generated from biogas is 2015/16 beating the our regulatory obligation and the targets set in the operational budgets

• £236M invested across nine sludge treatment centres since 2005

• Further investment planned to increase advanced digestion capacity to treat 100% of biosolids to enhanced treated standard

• Targeting a minimum of 105GWh/y power generation from biogas by 2020 with a further stretch target to generate 124GWh from our CHP fleet
SHAPING THE FUTURE TOGETHER

INNOVATION

TRANSFORMATION

COLLABORATION