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Global Challenges and Innovation in Wastewater and Sludge Treatment

Critical Challenges Facing Wastewater Treatment: Wastewater Treatment Intensification

CIWEM Technical Seminar, 4 December 2018

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In the 1850s the River Thames was polluted and dangerous
- It was called the 'Great Stink'!

It was the best of times, it was the worst of times, A Tale of Two Cities, 1859, Charles Dickens
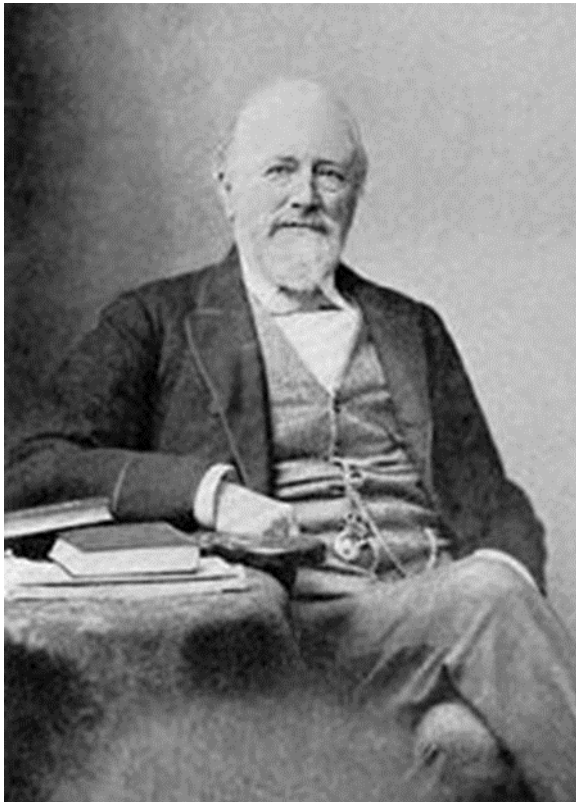

DIPHTHERIA   SCROFULA   CHOLERA

FATHER THAMES INTRODUCING HIS OFFSPRING TO THE FAIR CITY OF LONDON
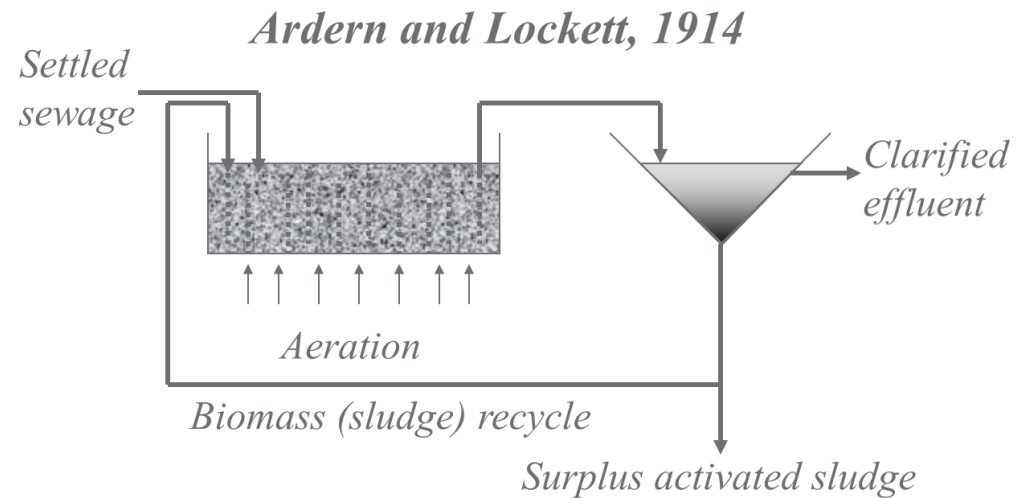(A Design for a Fresco in the New Houses of Parliament)
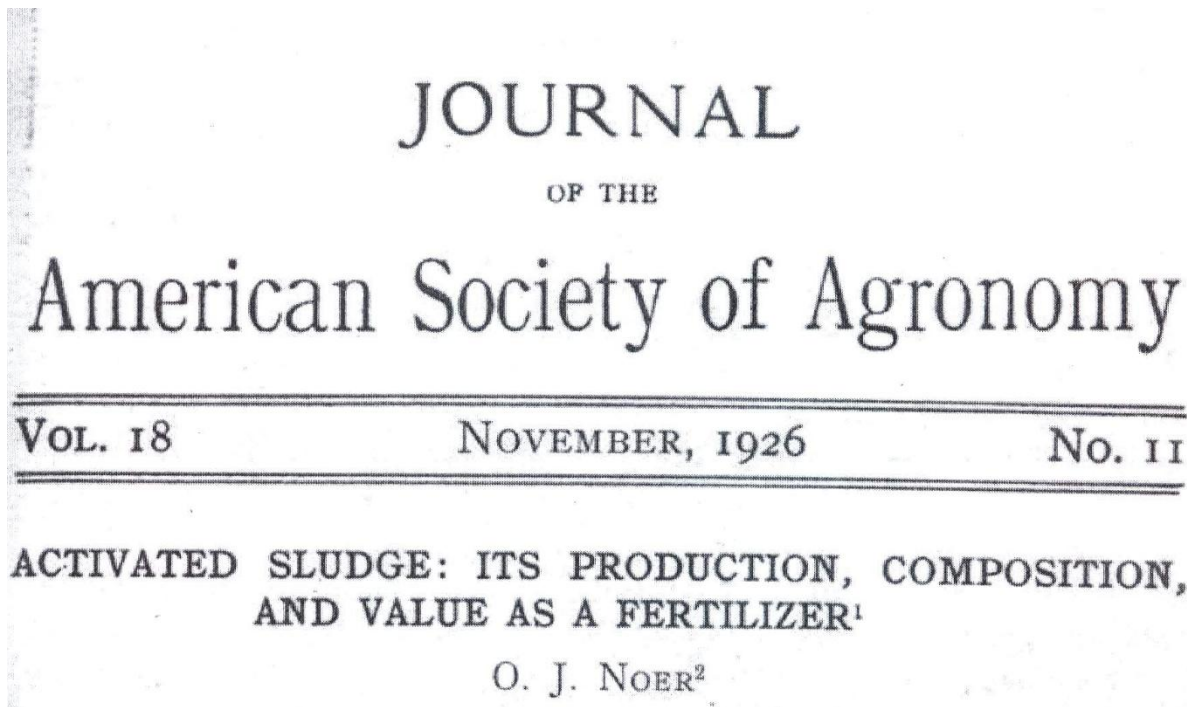

A DROP OF LONDON WATER

Sir Edward Frankland

1868 Sir Edward Frankland began a major study of filtration performance on raw London sewage in laboratory columns

© Imperial College London

Ardern and Lockett

Ardern and Lockett, 1914

Settled sewage

Clarified effluent

Aeration

Biomass (sludge) recycle

Surplus activated sludge

The Value of Activated Sludge as an Effective Fertilizer has been Understood for a Long Time:

JOURNAL

OF THE

American Society of Agronomy

VOL. 18   NOVEMBER, 1926   No. 11

ACTIVATED SLUDGE: ITS PRODUCTION, COMPOSITION, AND VALUE AS A FERTILIZER[1]

O. J. NOER[2]

6-2-0

Milorganite®

Fertilizer

✔ Use on lawns, flowers, vegetables, shrubs and trees
✔ No need to water in; waits for moisture to activate
✔ Nonburning: use anytime, even in midsummer
✔ Contains iron for deep, even greening

4% IRON

For Better Results. Naturally.

Net Weight: 40 lbs.

N Fertilizer Response to Activated Sludge

(a) Ammonium nitrate

(b) Activated sludge

Yield g/plant FW

Top kg N/ha

Base kg N/ha

Journal of Horticultural Science (1988) **63** (4) 615–620

A comparison of the effects of organic and inorganic nitrogen fertilizers on the growth response of summer cabbage (*Brassica oleracea* var. *capitata* cv. Hispi F₁.)

By S. R. SMITH and P. HADLEY

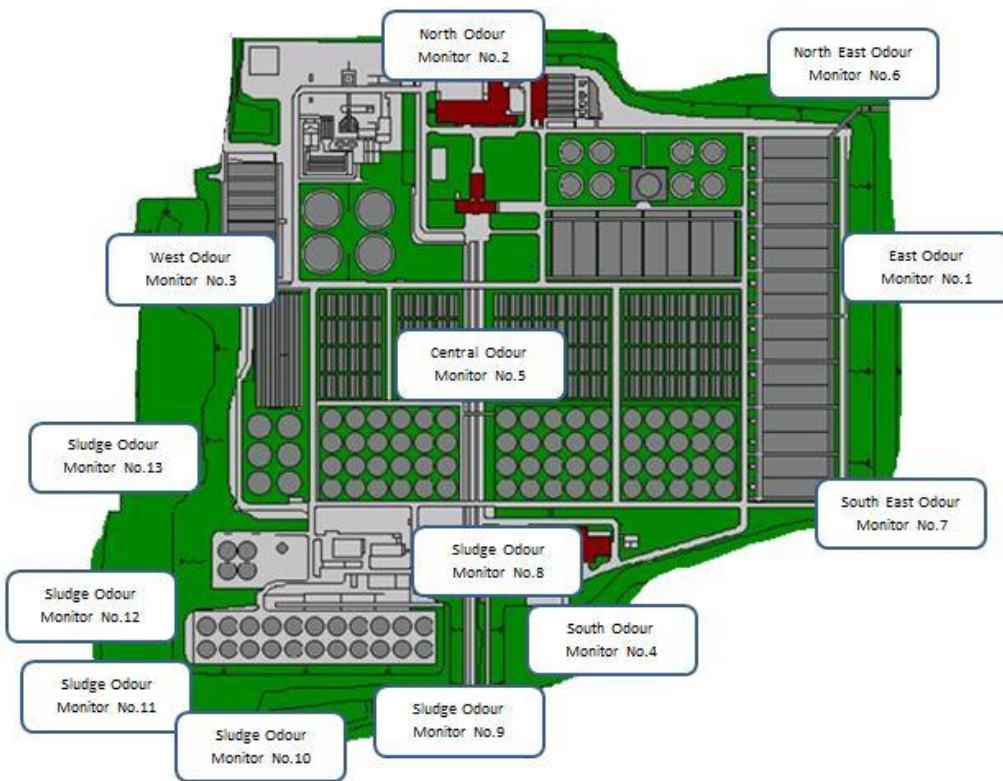Department of Horticulture, University of Reading, Earley Gate, Reading RG6 2AU, UK
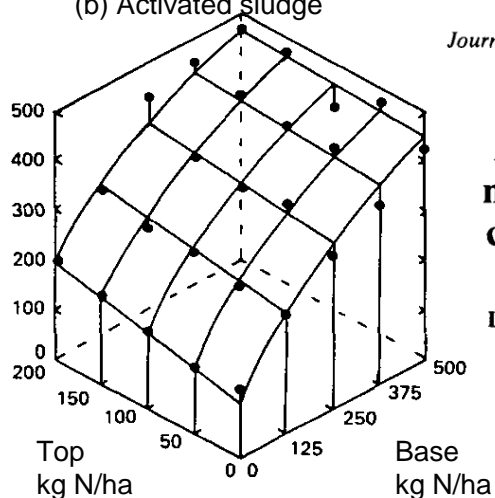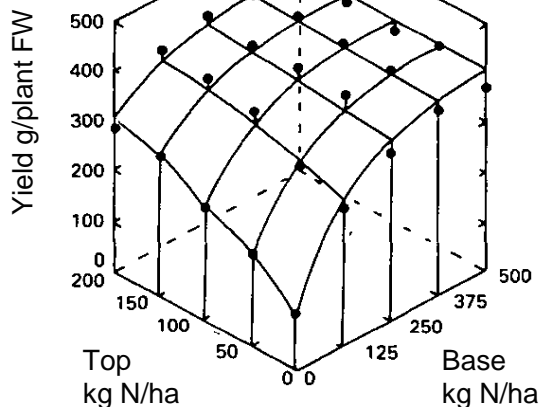
First Anaerobic Digester

First municipal treatment of wastewater in septic tanks began in Exeter in 1897.

The methane gas was used for heating and lighting at the treatment works

Mogden Sewage Treatment Works

Built in the 1930s

Serves 1.9m people

140 acre site

Upgraded 2013

Treats 1064mega L/d

Climate Change

- 'Greatest long-term challenge facing the world today'
  - IPPC Climate Change 2007 *Synthesis Report*
  - IPPC Climate Change 2014 *Synthesis Report*, 2017 (5th)

Intergovernmental Panel on Climate Change (IPPC) - http://ar5-syr.ipcc.ch/topic_observedchanges.php
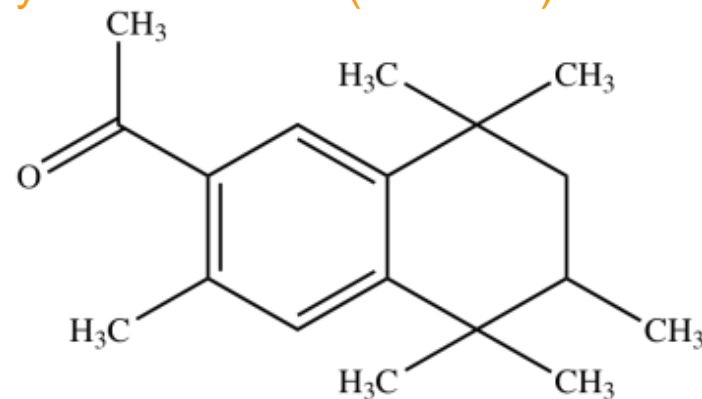
DEHP
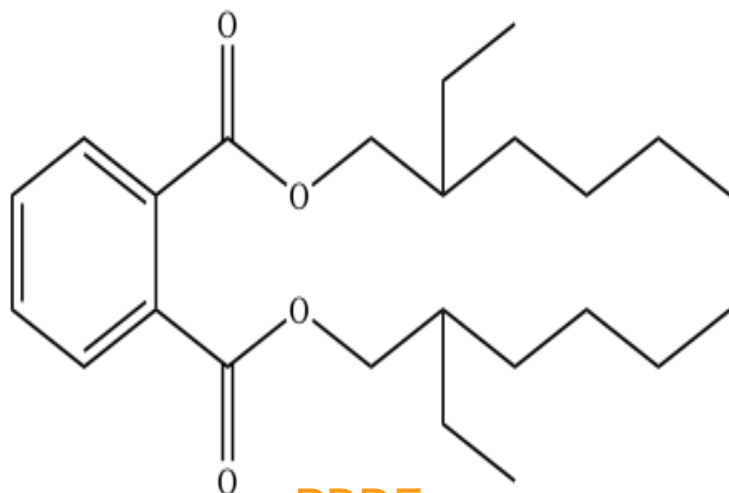
PFCs
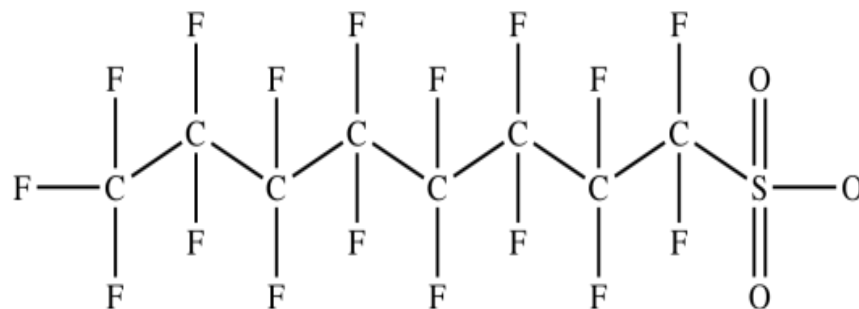
PBDE
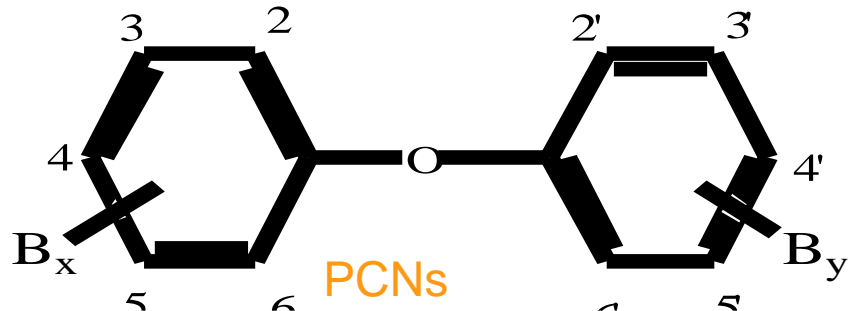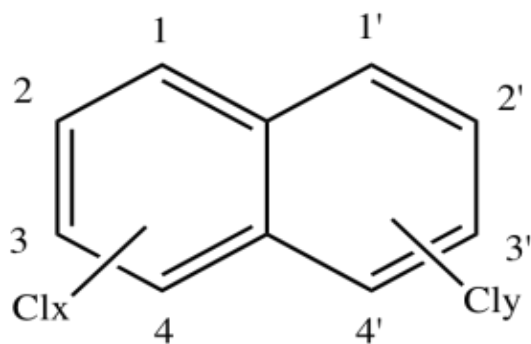
17 α-ethinyloestradiol

PCNs
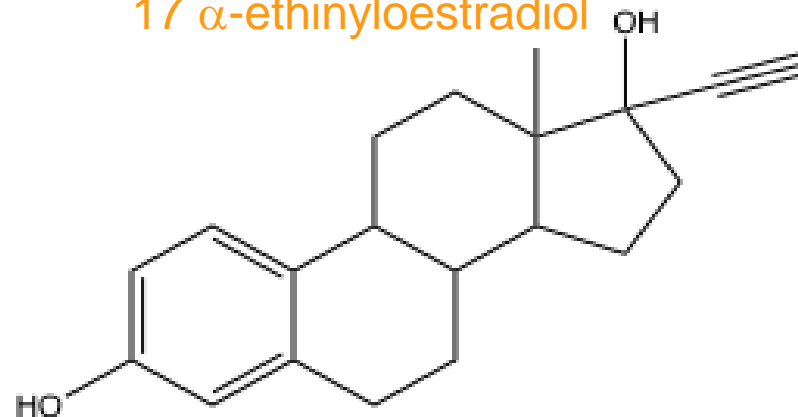
Synthetic Musks (Tonalide)

Resource Conservation and Recovery
Peak Phosphate Production

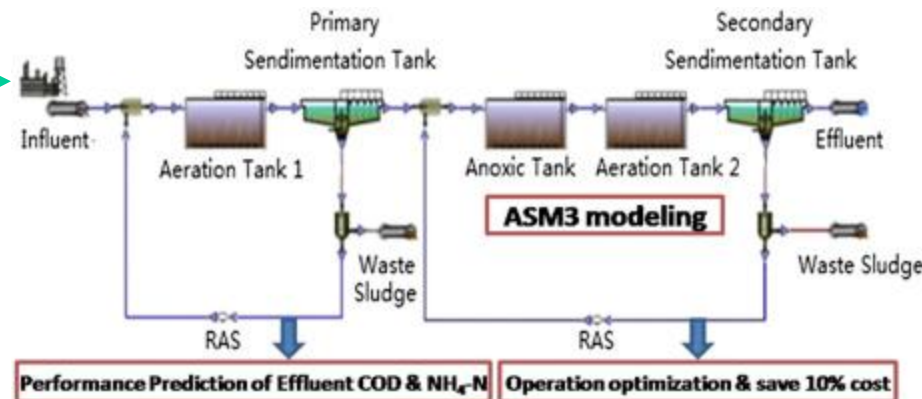**PHOSPHATE ROCK PRODUCTION**
1900-2100
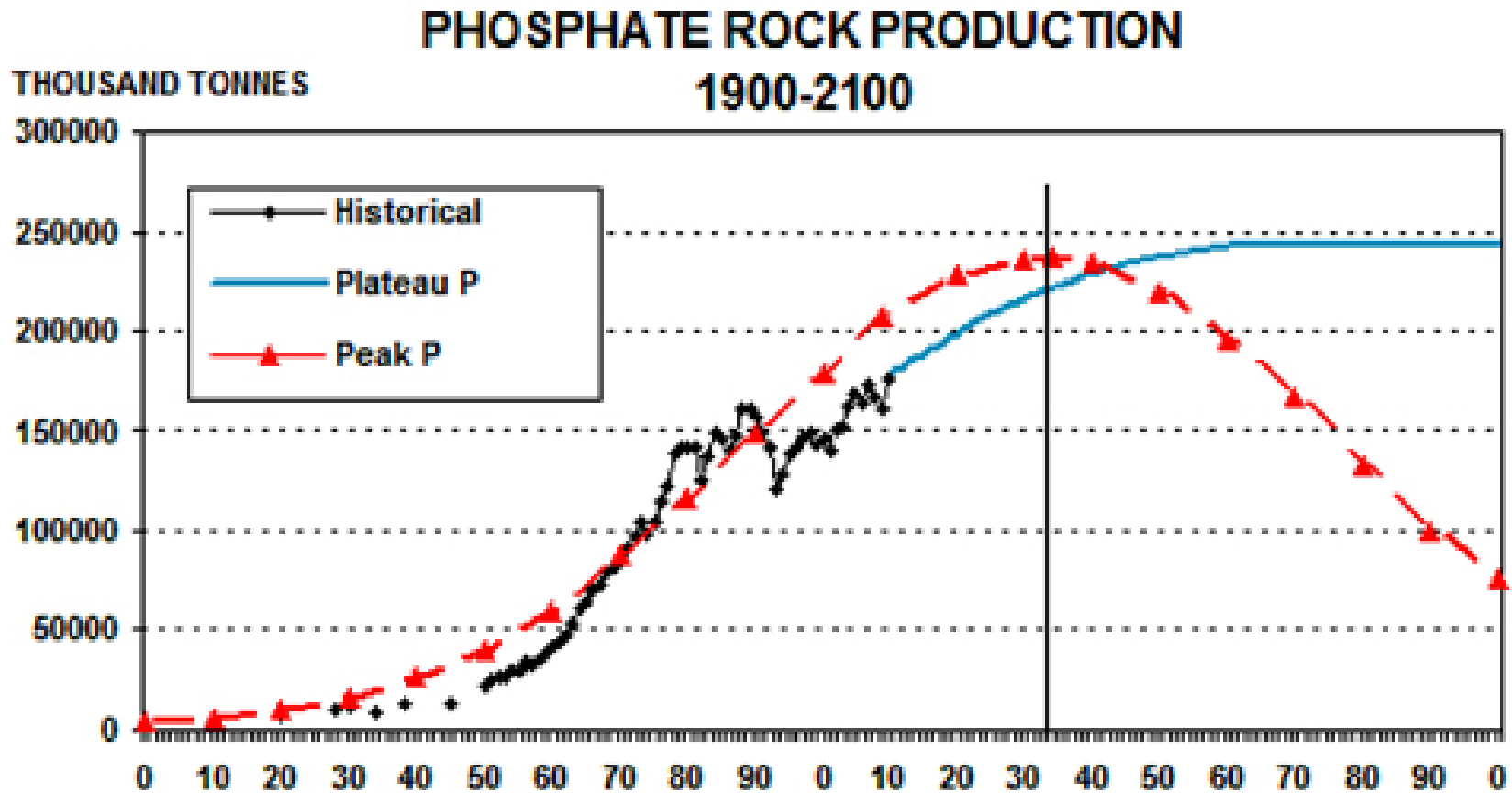
We cannot solve our problems with the same thinking we used when we created them.

Albert Einstein

How to address the challenges of:

– Process intensification

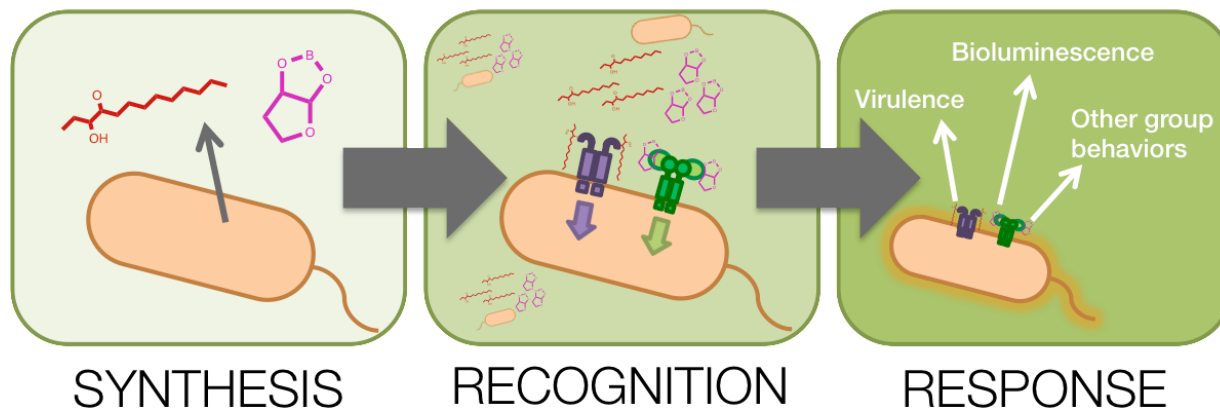– Resource recovery and efficiency

– Contaminant management

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Bioengineering Wastewater and Sludge Treatment

Biocatalysis

- Microvi MicroNiche Engineering technology
- Microenvironment of biological systems is synthetically designed to enhance microbial physiology and optimize enzymatic performance
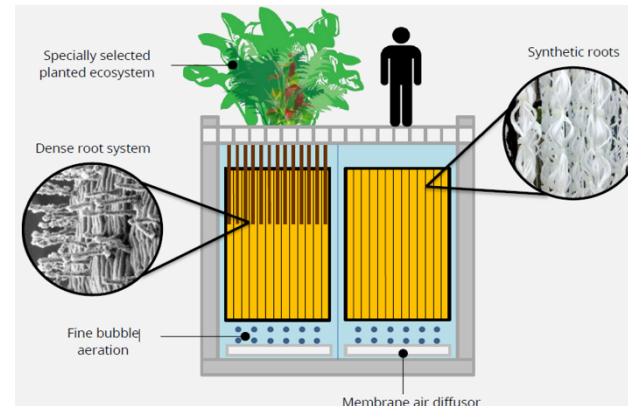- N and contaminant removal + other applications eg bioethanol, biobutanol production
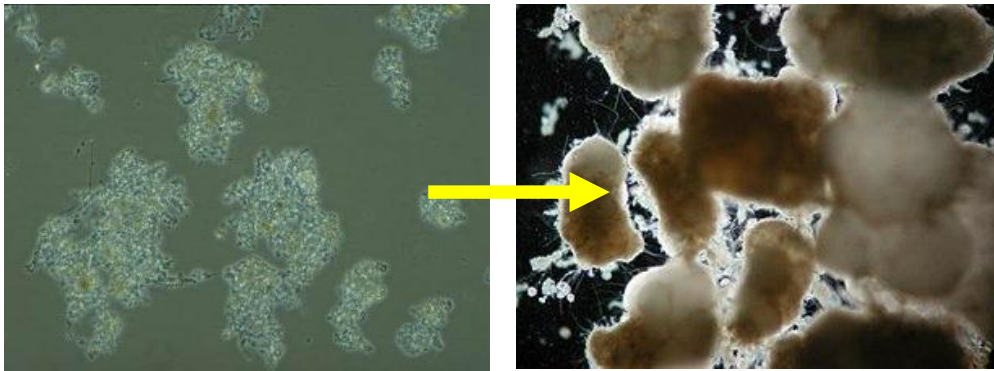
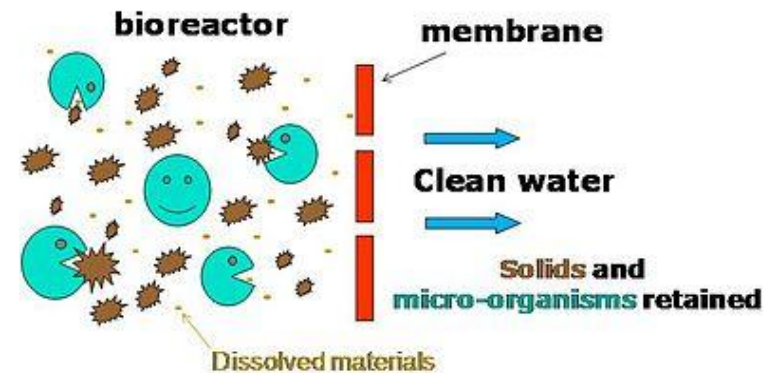## Quorum Sensing (Microbial Signalling)

SYNTHESIS   RECOGNITION   RESPONSE

Bioluminescence

Virulence

Other group behaviors

© Imperial College London

Wastewater Treatment Intensification

Integrated Film/Hybrid AS Systems

Specially selected planted ecosystem

Synthetic roots

Dense root system

Fine bubble aeration

Membrane air diffusor

Granular AS Systems

Membranes

bioreactor

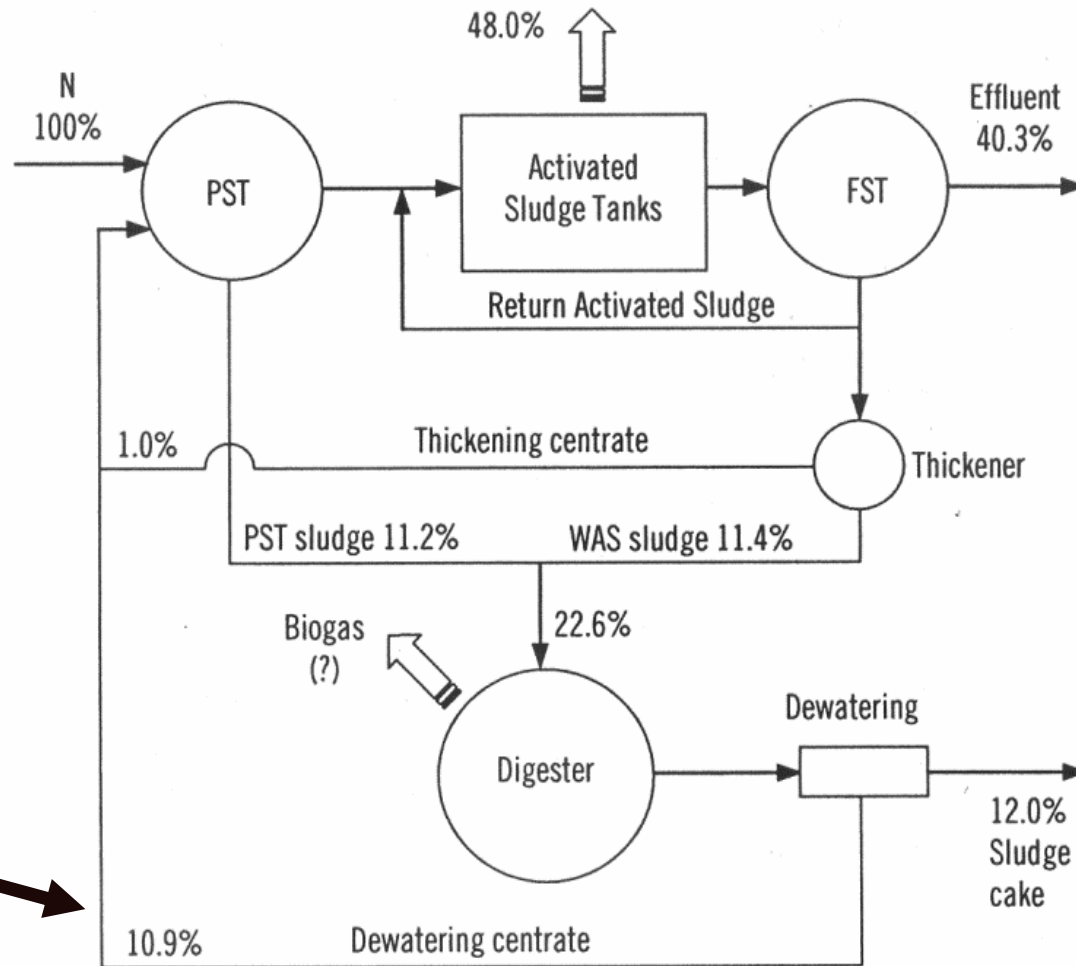membrane

Clean water

Solids and micro-organisms retained

Dissolved materials

Wastewater Treatment and Sludge AD - N Balance

Increases to ~20% with struvite recovery

International Research Output (by Year)

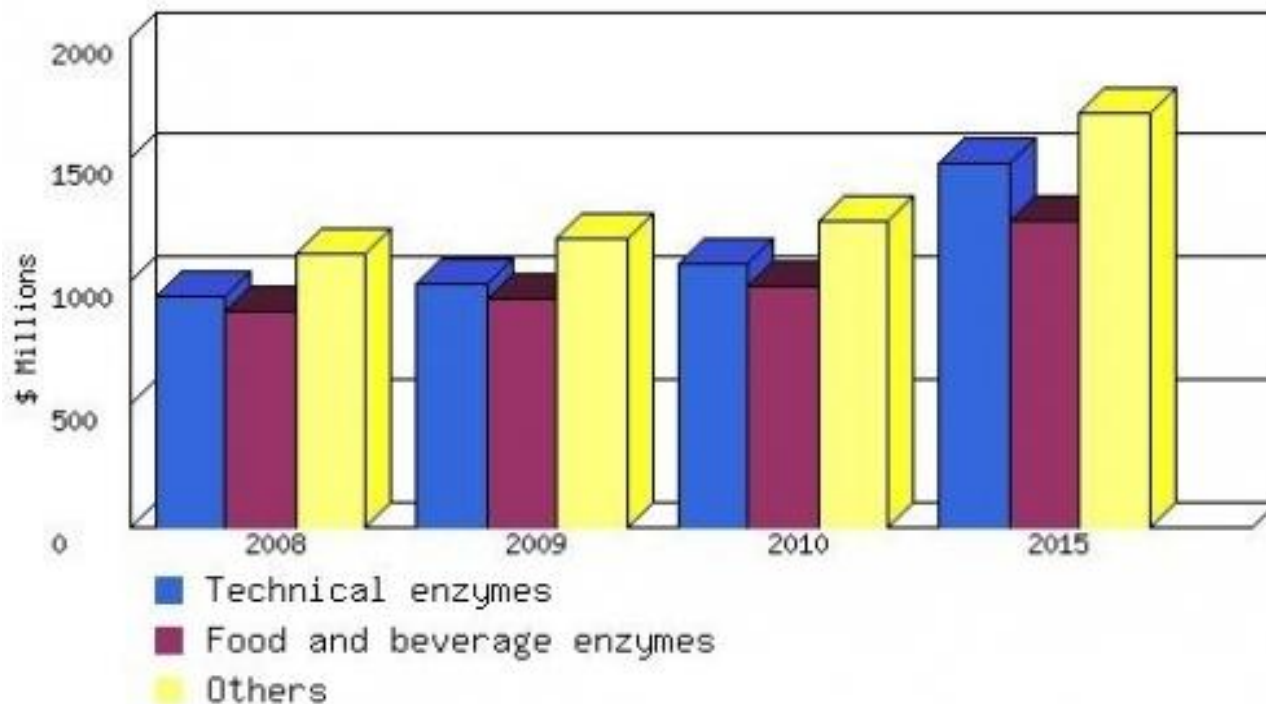*Results of Web-of-Science search: Activated AND Sludge AND Resource*
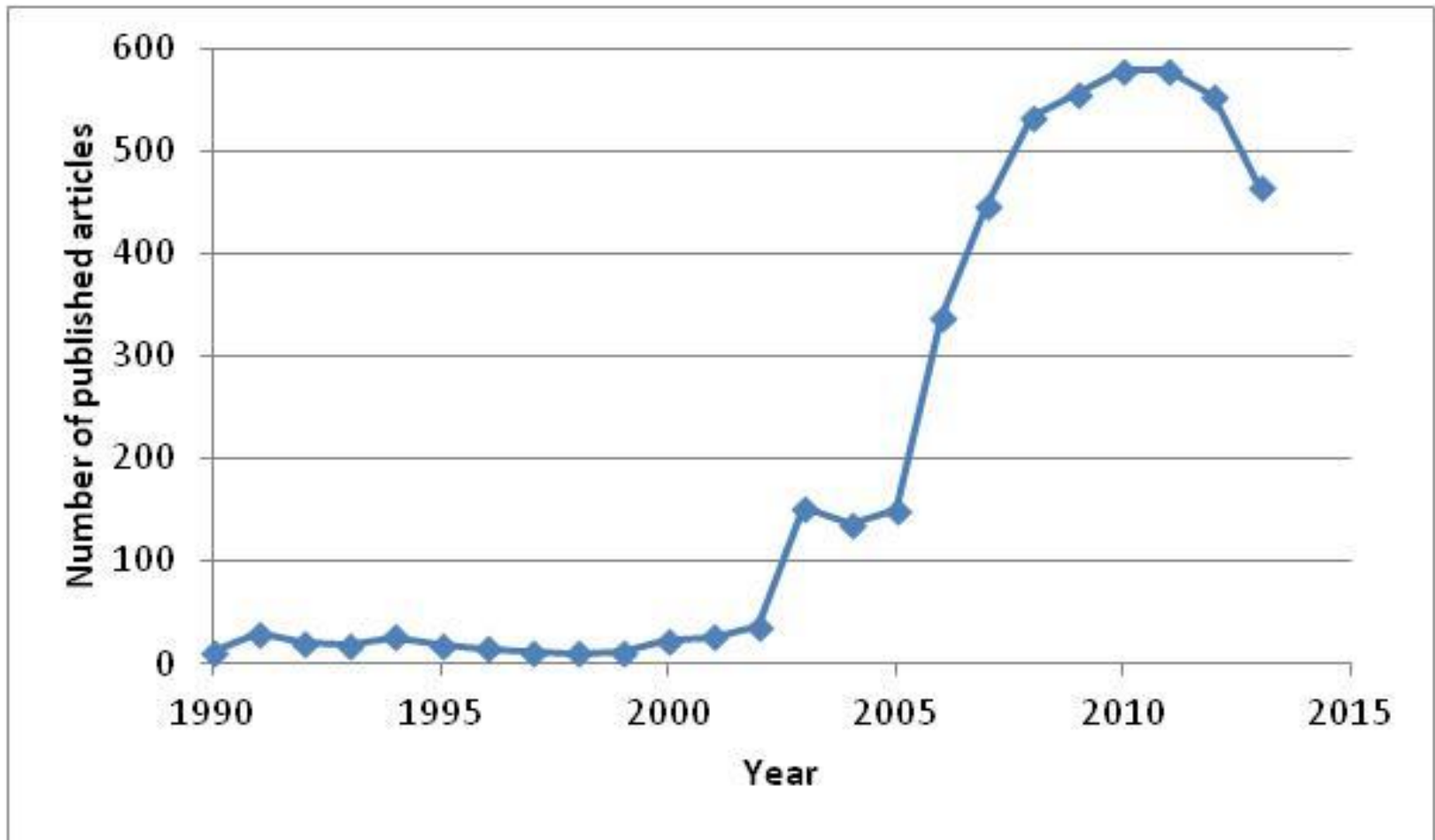
International Research Output (by Country since 1950)

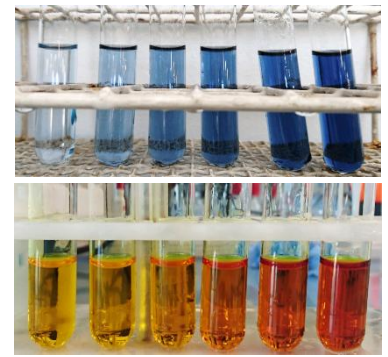*Results of Web-of-Science search: Activated AND Sludge AND Resource*
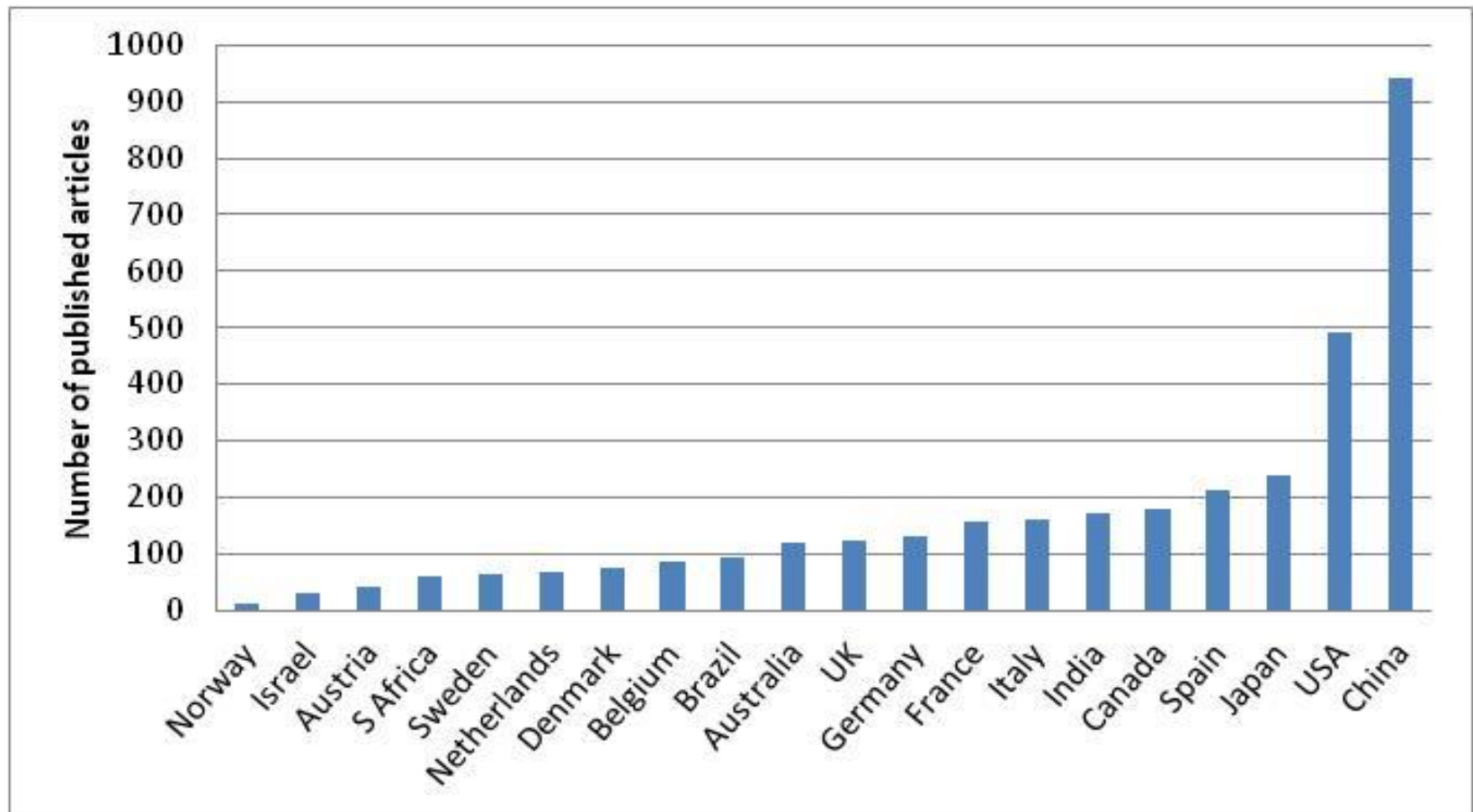
Bioenzyme Recovery from Activated Sludge

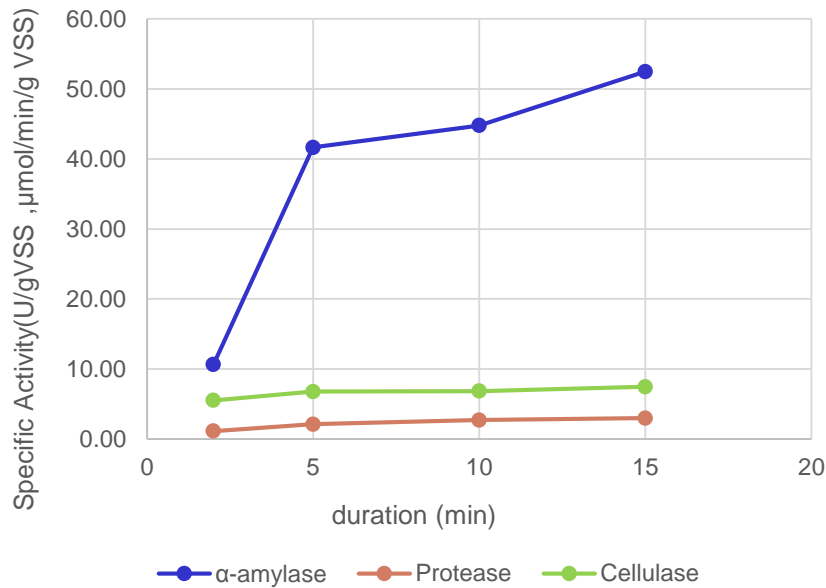## Global bioenzyme market >£3 billion in 2017

© Imperial College London

Enzyme quality similar to commercial products

Enzyme assays

Extracted enzyme activities

- α-amylase
- Protease
- Cellulase

Extracted enzyme activities
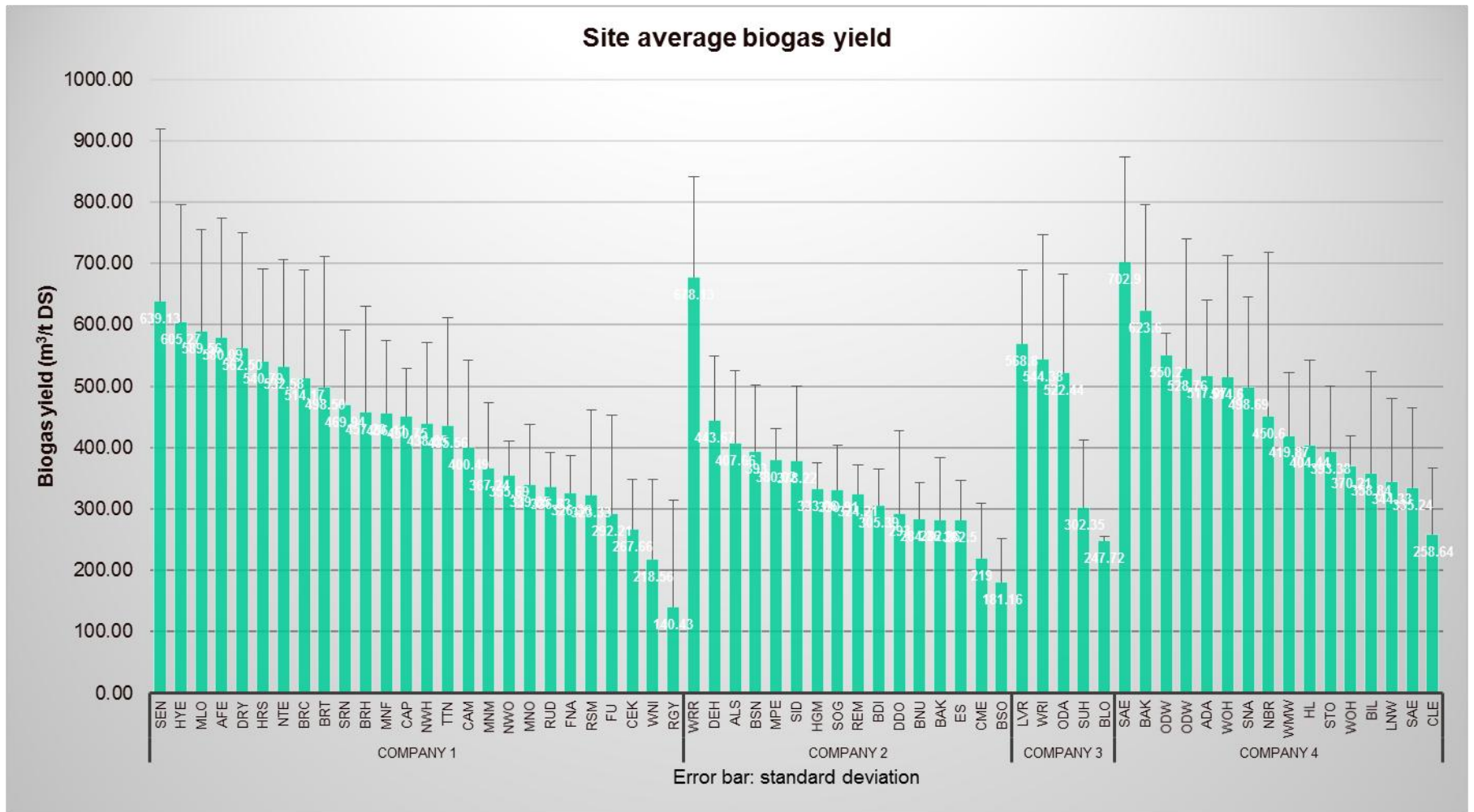

- α-amylase
- Protease
- Cellulase

1. Duration:
@ 10min
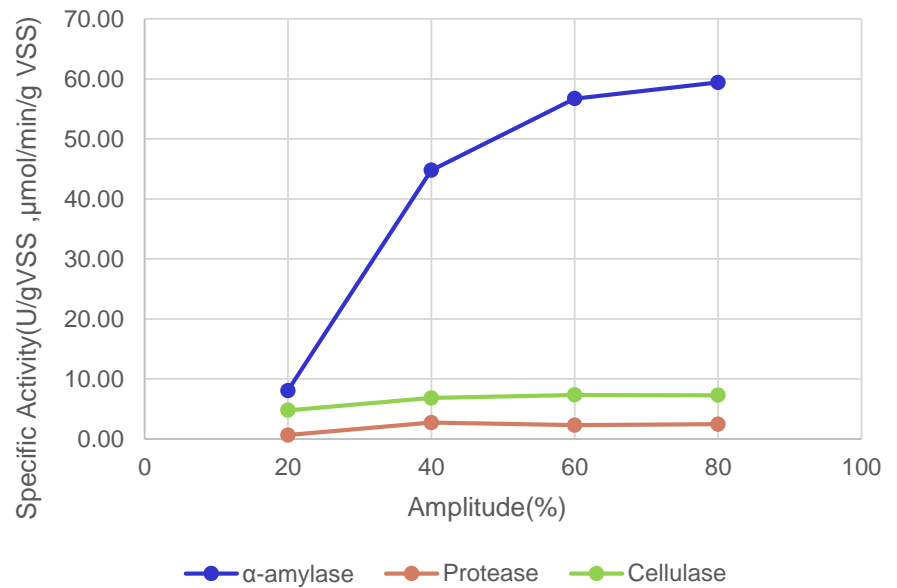
2. Energy intensity-Amplitude:
@ 40%

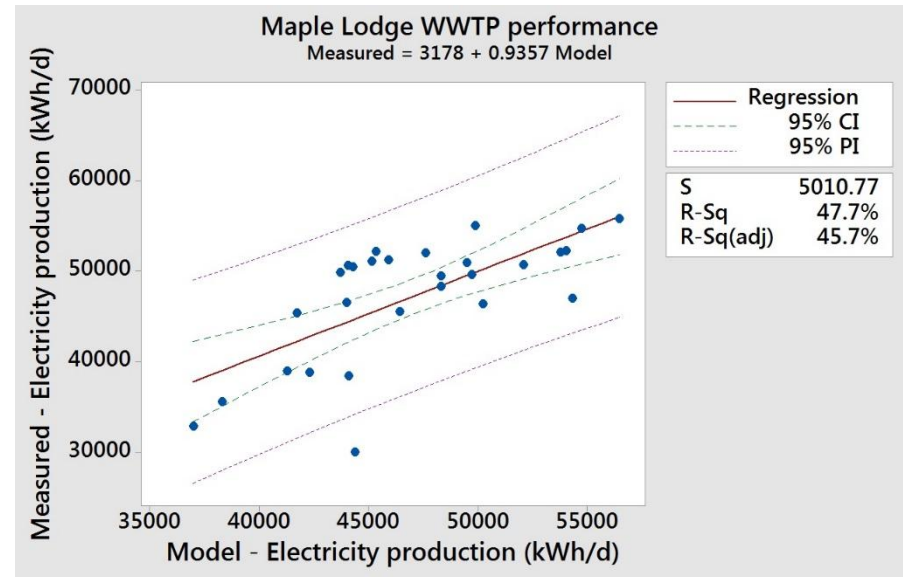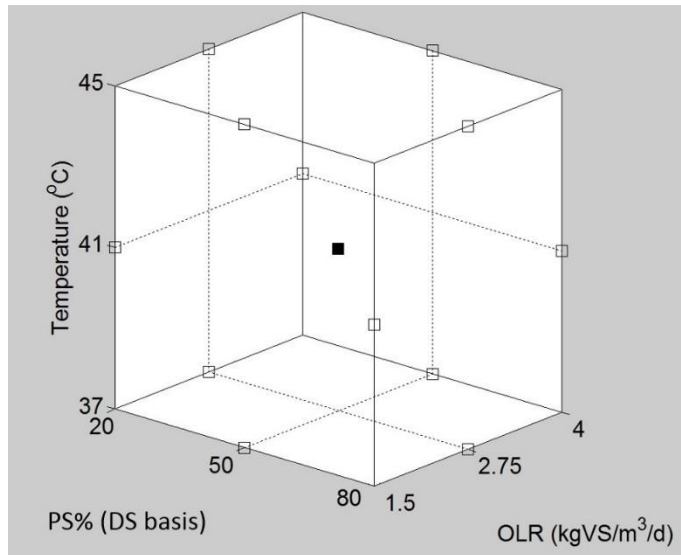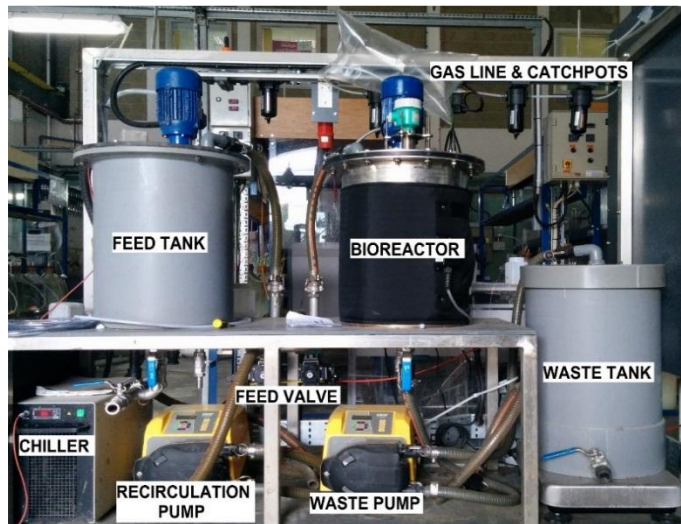# It is hard to imagine a future without AD

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AD Big Data: Average Site Specific Biogas Yield
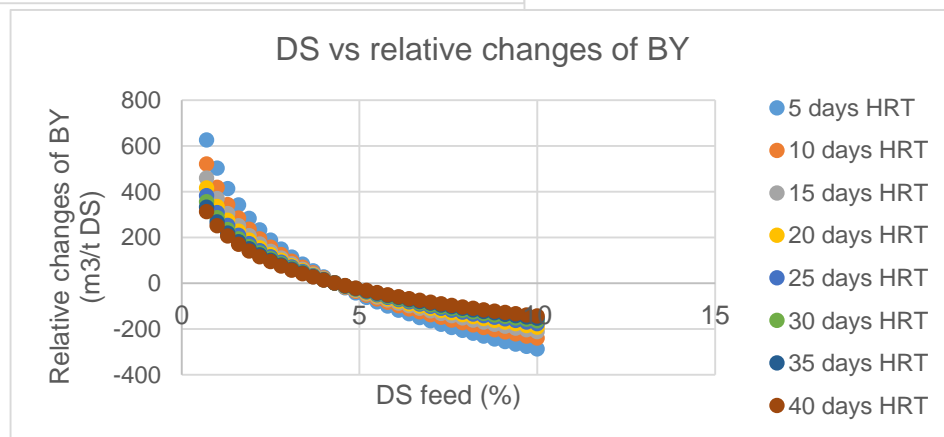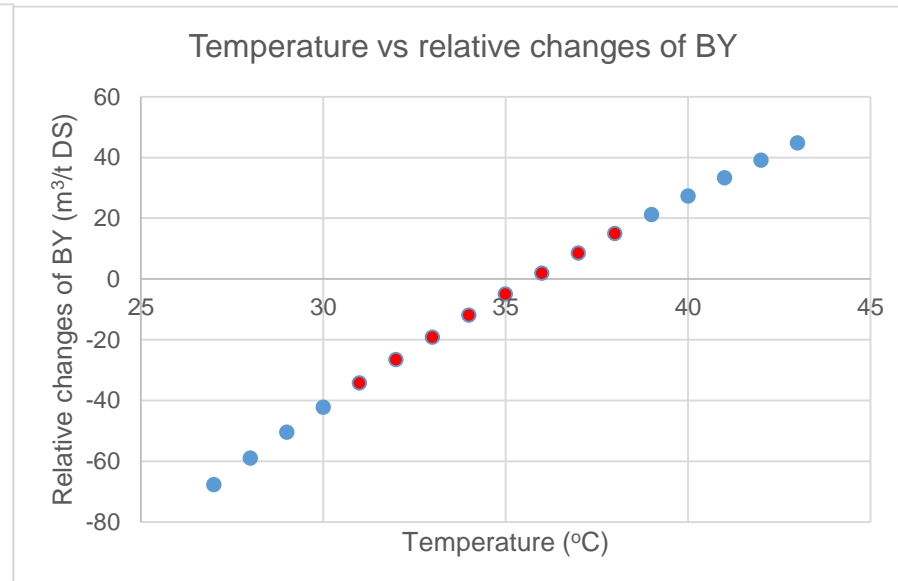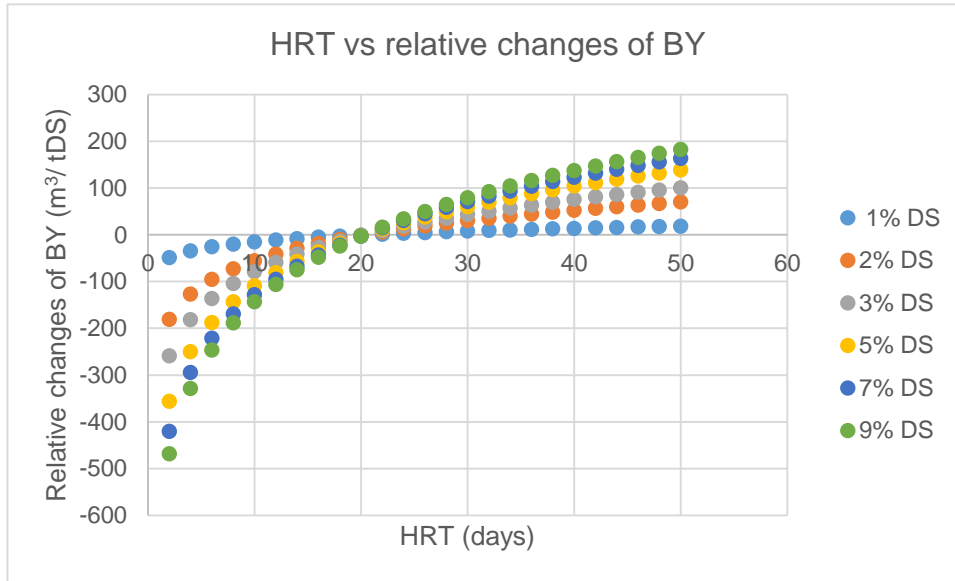
Overview of the conventional MAD dataset

Site average biogas yield

Integrated Functional Model for AD Management
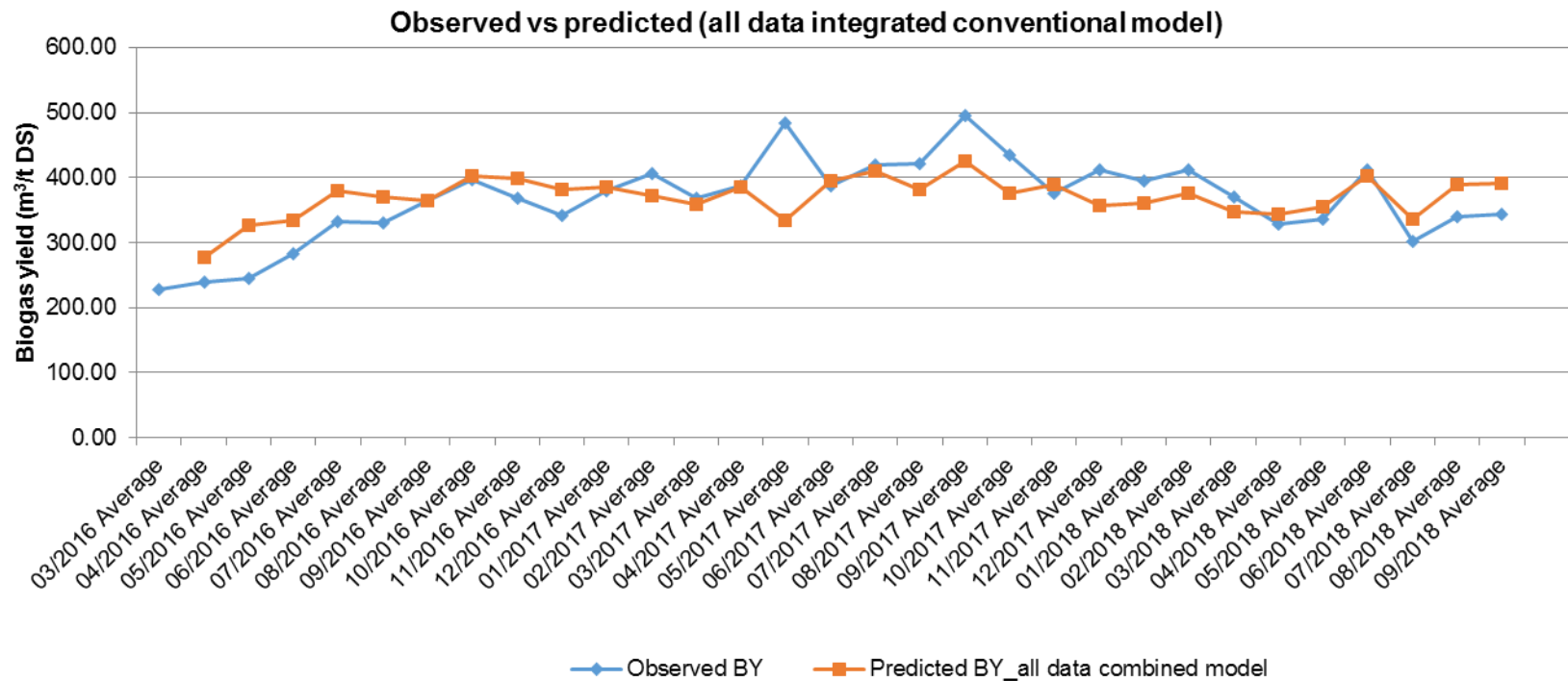
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AD Big Data - Multiple Regression Model

All data integrated models – Conventional MAD natural logarithm with interaction

Statistical Big Data AD Model Validation

All data integrated conventional MAD model monthly average

Conclusions

- Bioengineering WW and sludge treatment
- Rhetro fit technologies
- Develop and apply operational models for decision support and intensity optimisation
- Adopt a resource management strategy:
  - Technological opportunities leading to greater diversity, resilience and revenue streams