In situ resource recovery from waste repositories

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Presentation overview

- Introduction
  - Wastes and waste repositories
  - Taxonomy of In situ techniques
- INSPIRE Project
- Technologies
  - Technology readiness levels
  - Some examples
- Case study
- Future avenues for research

Wastes and the Waste Repositories

- Ore deposits of the ‘anthropocene’
- Historically deposition of vast quantities of:
    - industrial,
    - municipal,
    - metallurgical and
    - mining wastes

  into or onto the ground.
- Effectively have put resources into geological storage e.g.:
    - Metals, nutrients and
    - energy (in the form of biomass and polymers)…….
    - & land

Historic mines sites in England and Wales

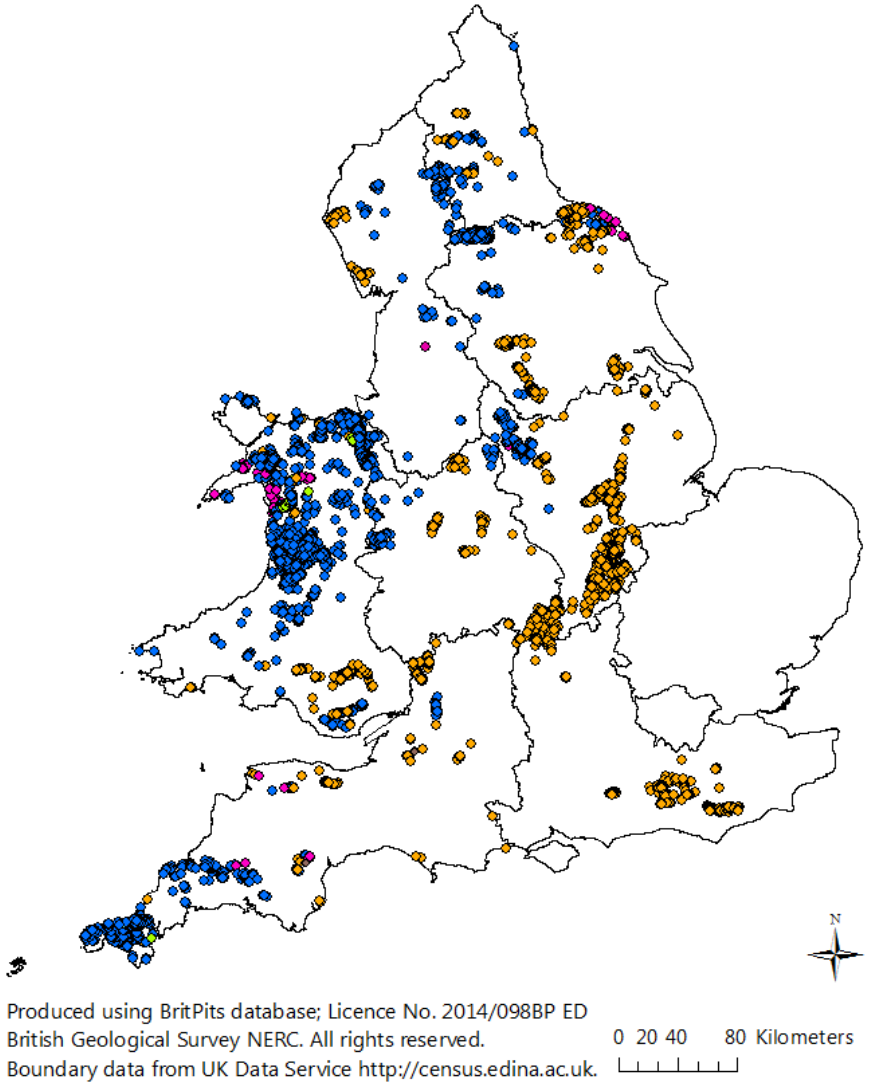
≈100,000 mines in England and Wales

Maps courtesy of Dr Danielle Sinnett, Unversity of the West of England, UK

Metal mine sites in England and Wales

8239 closed metalliferous mine sites in England and Wales

- Cu, Pb, Zn, Ba, W, Sn, Sb, As
- Fe
- Au, Ag
- Al, Mg



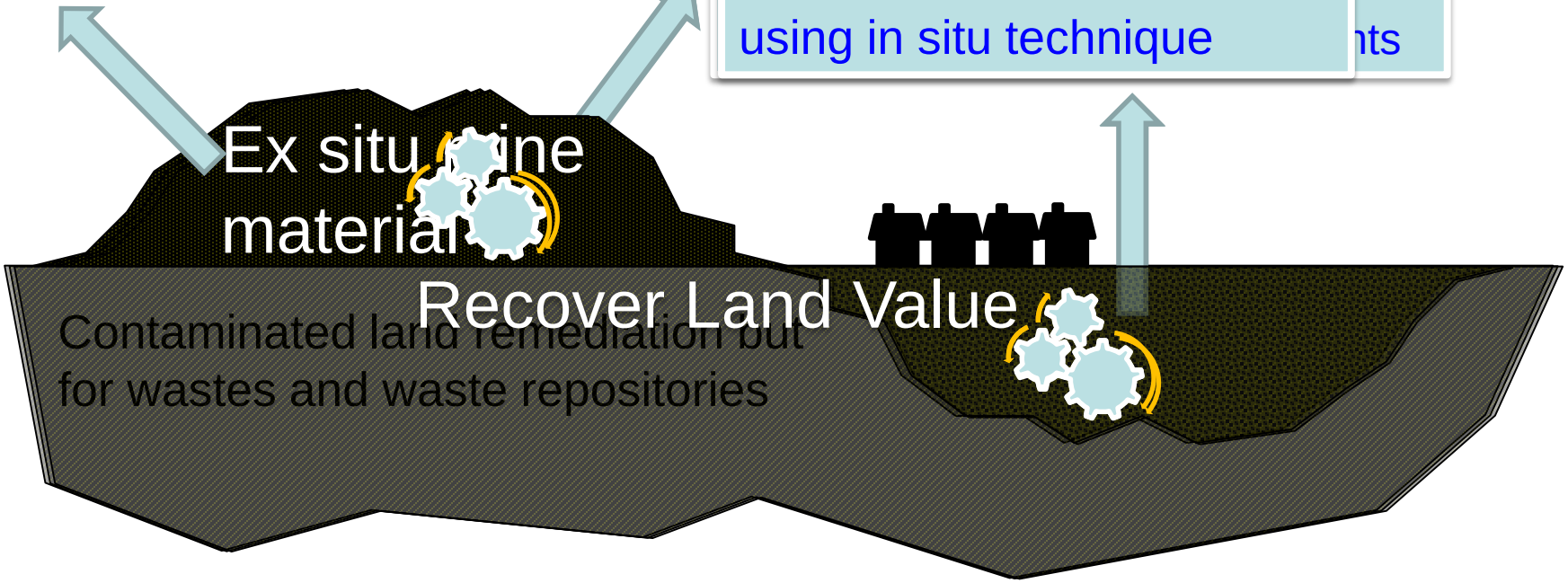
Maps courtesy of Dr Danielle Sinnett, Unversity of the West of England, UK

Taxonomy of in situ technologies

- Direct Recovery
- Indirect Material Recovery:
- Indirect Land Recovery: La

(i) Energy (via stimulation, capture and combustion of methane)

Remove contamination using in situ technique



- or combination to work towards zero-waste…..

Active or Passive???

‘Heap’ leaching

‘Passive’ leaching of metals

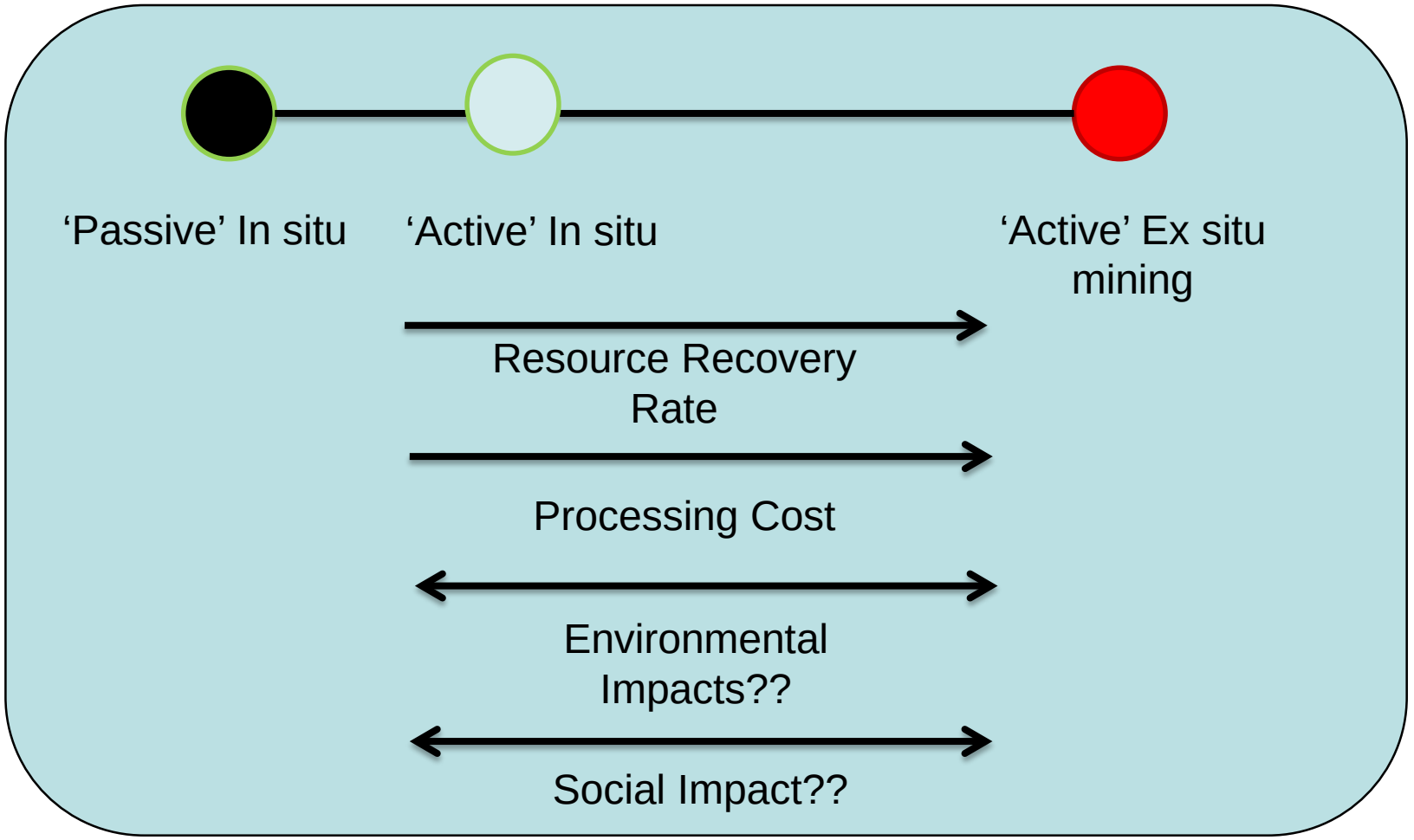
Microbial ‘Heap’ leaching

‘Active’ conventional mining

Increasing
Energy (cost) →
← Impact ? →
Recovery→

Why in situ? or Why not ex situ?

- Balancing: Environmental – Economic – Social - Technical



INSPIRE Project

- £1.3 million
- 3.5 Years Mid 2014 – End 2017
- Multi-disciplinary: Engineering; Bioscience; Planning
- Considering resource extraction from the full range of wastes currently in UK waste repositories including industrial and commercial waste, incinerator and fuel ash, mineral and municipal wastes.

INSPIRE Project: Key questions

INSPIRE Project Focus

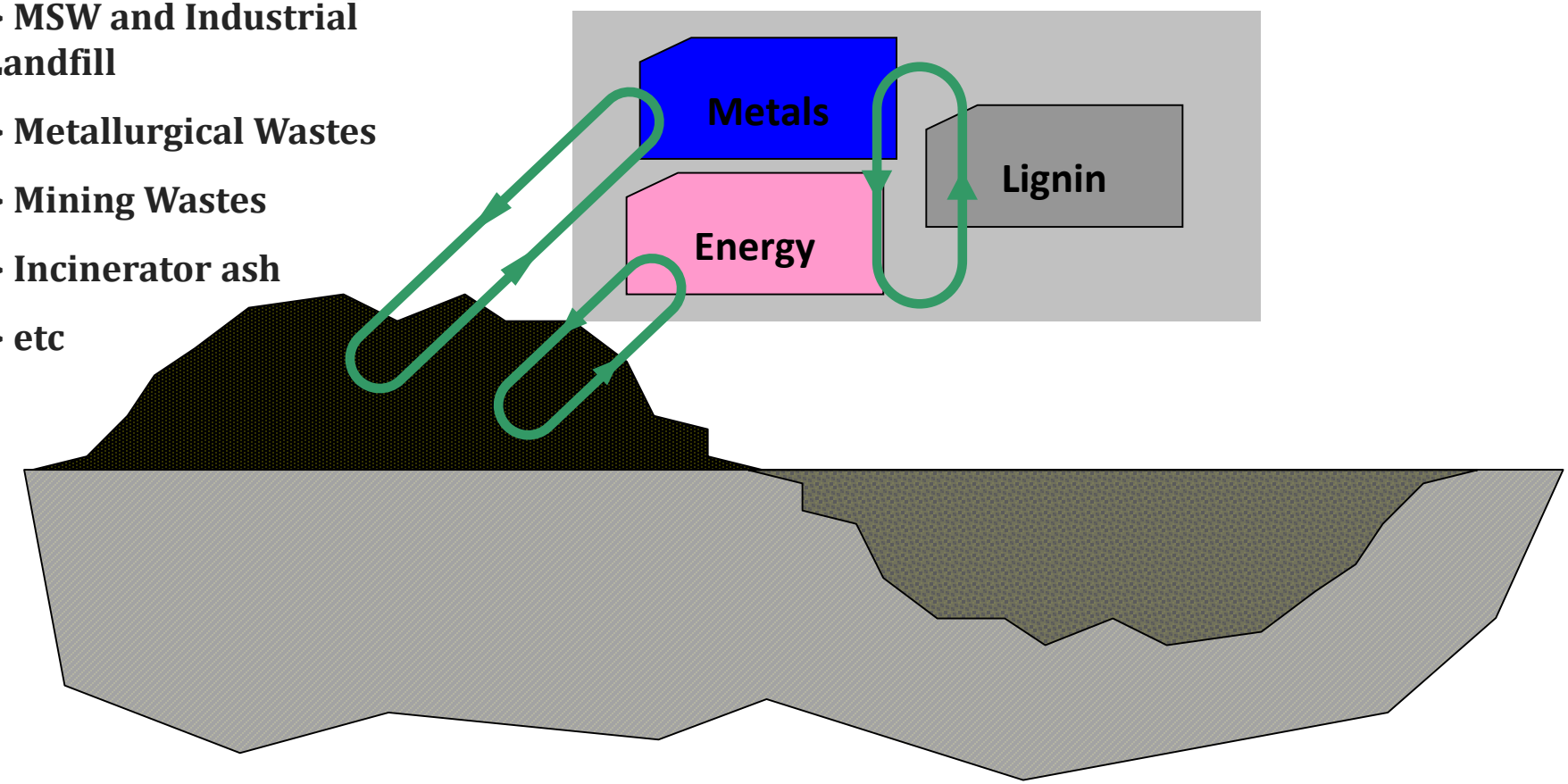
> MSW and Industrial Landfill

> Metallurgical Wastes

> Mining Wastes

> Incinerator ash

> etc

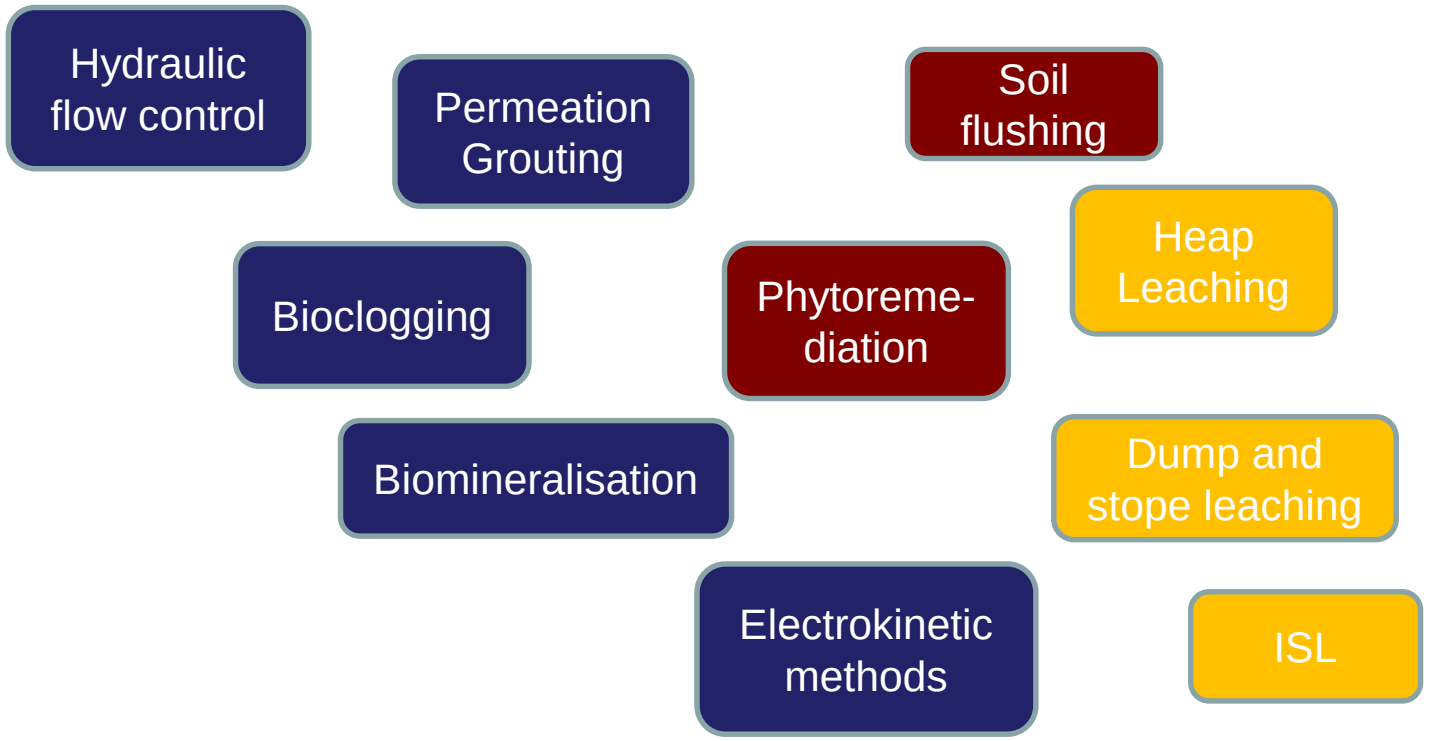


[1] MOBILISE → [2] FLOW PHENOMENA THROUGH COMPLEX MEDIA → [3] SELECTIVE RECOVERY OF RESOURCES

Potential Technologies

- Control of preferential flow
  - Hydraulic flow control
  - Permeation grouting
  - Bioclogging
  - Biomineralisation
  - Electrokinetic methods
- Contaminated land remediation technologies
  - Soil flushing
  - Phytoremediation
  - Electrokinetic methods
- Mining technologies
  - Heap Leaching
  - Dump and stope leaching
  - In situ leaching (ISL)

Technology Readiness Levels

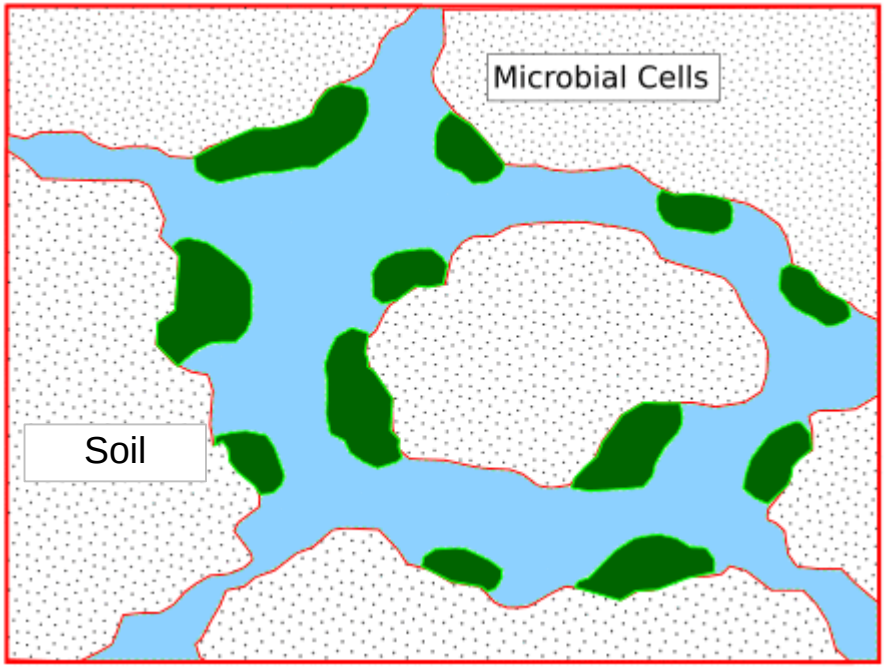


TRL	1	2	3	4	5	6	7	8	9
Technology Readiness level	Basic principles observed	Technology concept formulated	Experimental proof of concept	Technology validated in lab	Tech valid in relevant environment	Tech demo in relevant environment	System prototype demo.	System complete & qualified	Actual system proven

Preferential flow/ bio-clogging

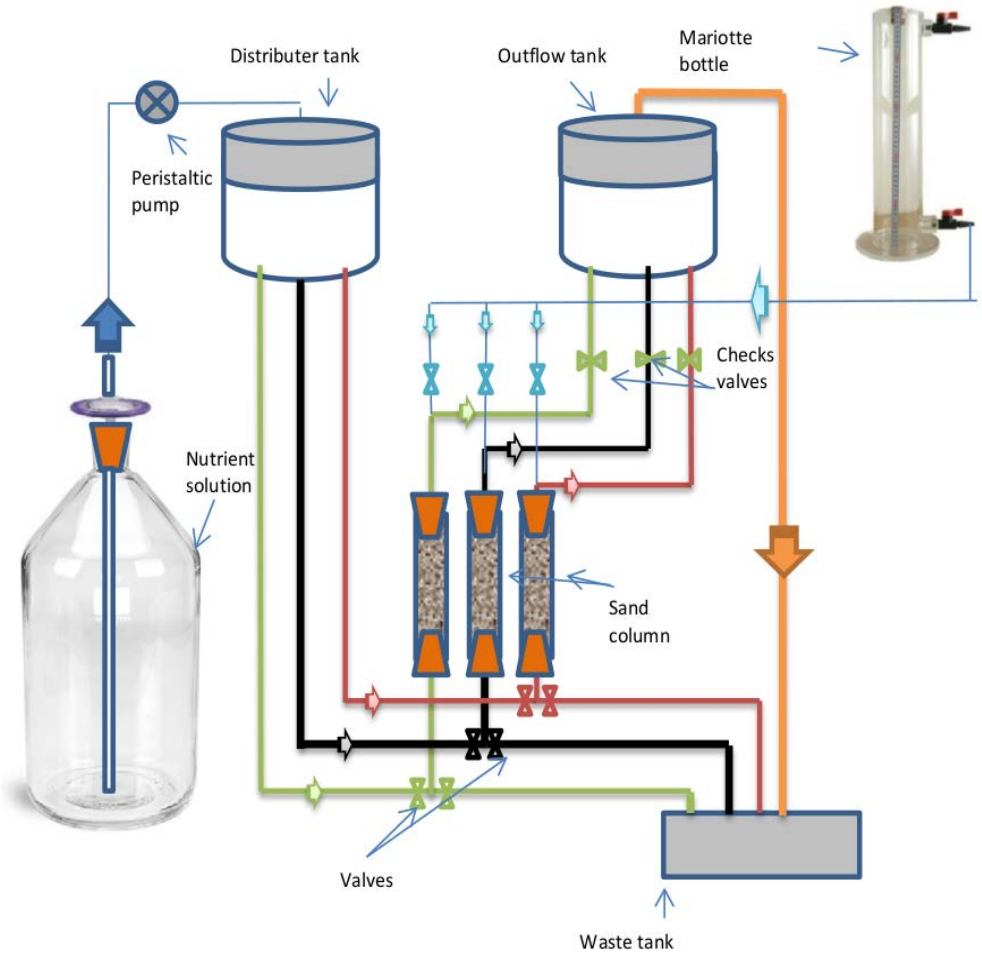
Development of model to describe the growth of bacteria in unsaturated wastes and its impact flow

Use of this model to explain bio-clogging effects observed in experiments then to engineer flow behaviour in wastes.



Preferential flow/ bio-clogging

- Currently applying model to investigate the impact of bacterial growth on the hydraulic conductivity of sands (experiments undertaken at Cardiff University)
- Aim is to used controlled bio-clogging to block preferential pathways and increase access to target resources

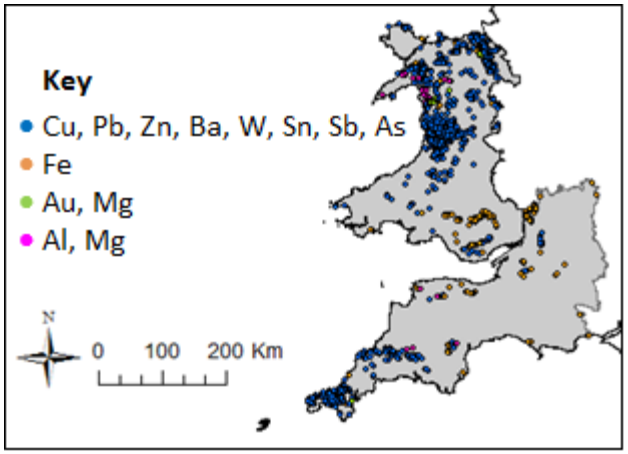


Alshiblawi (2016): Harbottle & Alshiblawi (2016)

Other work (experimental & numerical) underway

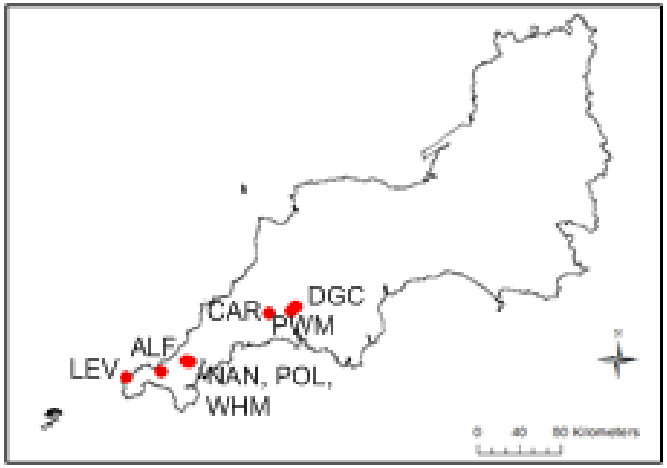
Case study

- Legacy mine sites in south west England and Wales
- Physicochemical composition of wastes => Estimates of resource potential
- Co-located landscape designations
- Implications on resource potential



Crane, R.A., Sinnett, D.E., Cleall, P.J., and Sapsford, D.J., 2016 “Physicochemical composition of wastes and co-located landscape designations at legacy mine sites in south west England and Wales: implications on resource potential” In press in *Resources, Conservation & Recycling*

Co-location of sites

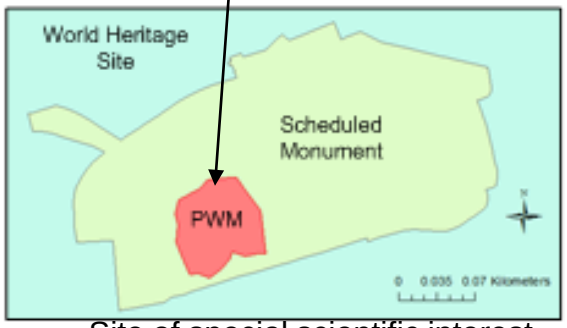


>65% of sites co-located with some kind of cultural or ecological designation (often due to the original activity)

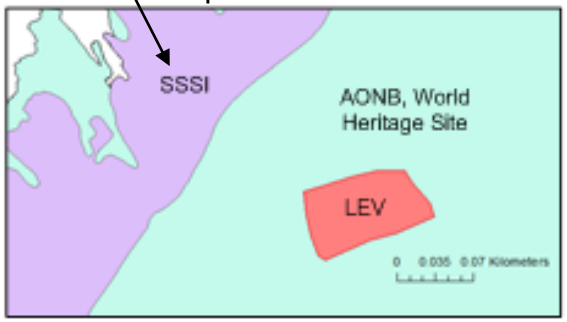
Complex interaction with geological, ecological and cultural designations.

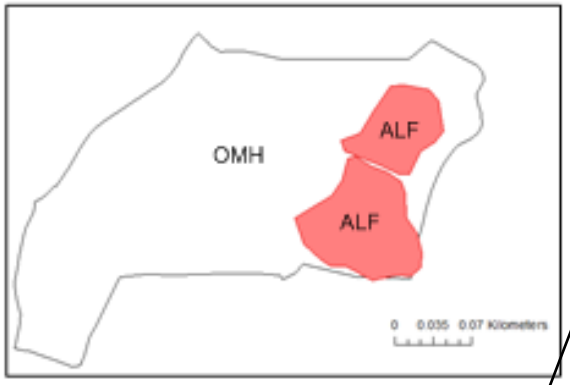
See Crane et al. (2016)

Site location

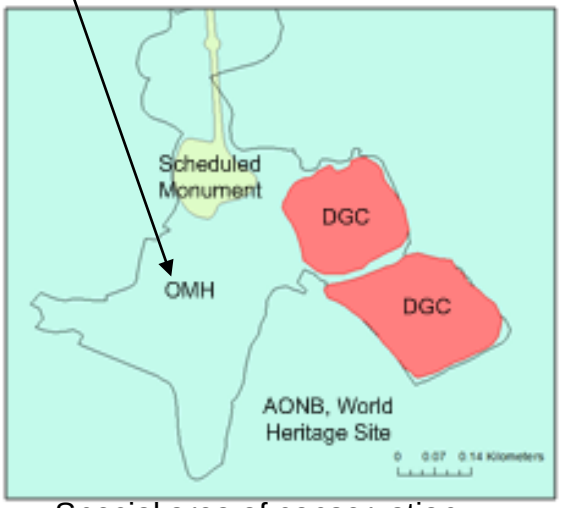


Site of special scientific interest

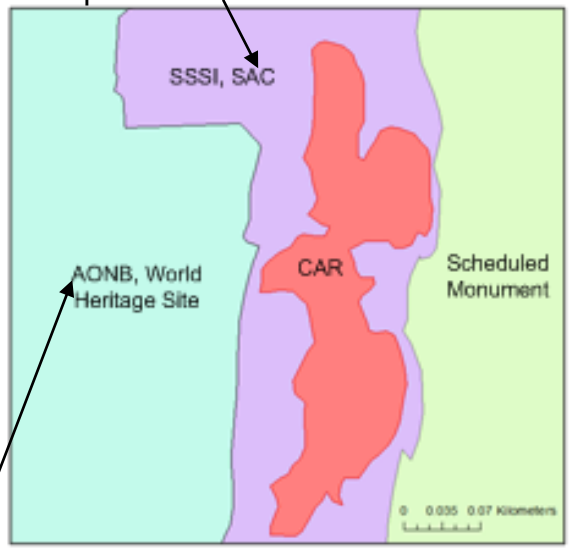




Open Mosaic Habitat

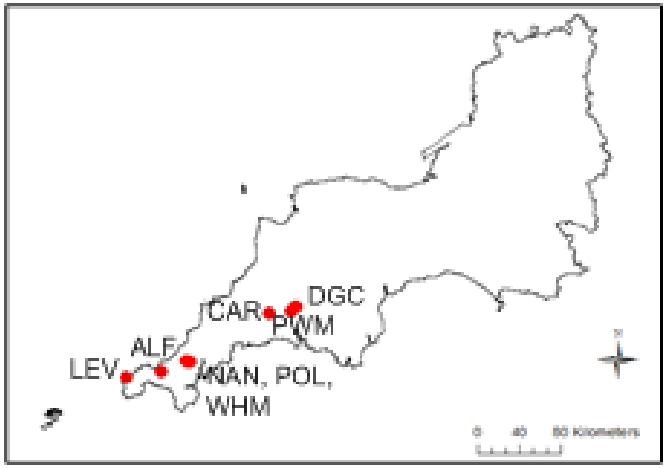


Special area of conservation



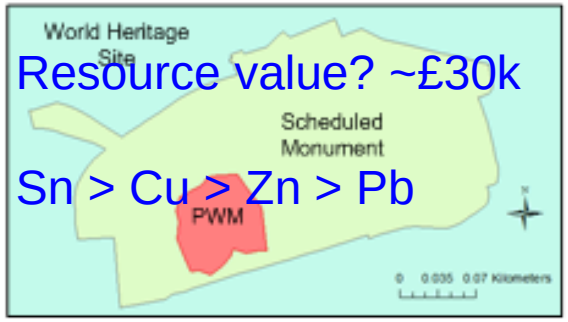
Area of outstanding natural beauty

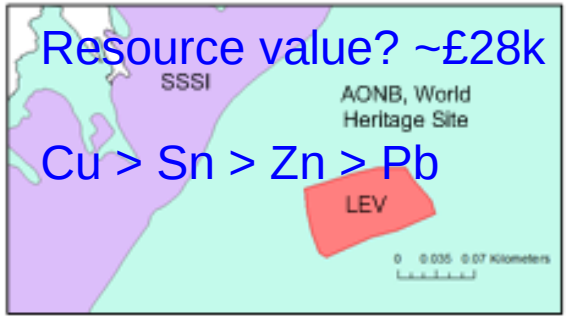
Potential resource value of sites

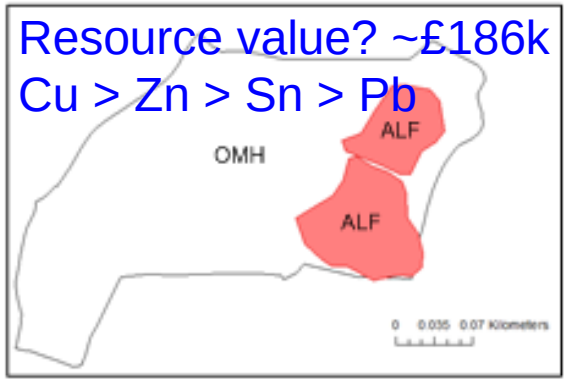


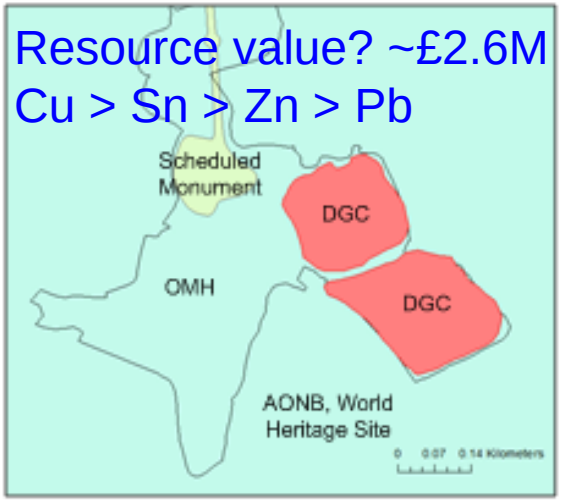
Surface sampling
- -0.2 m depth, 6-8 kg
- -composite samples
- -XRD, ICP-OES

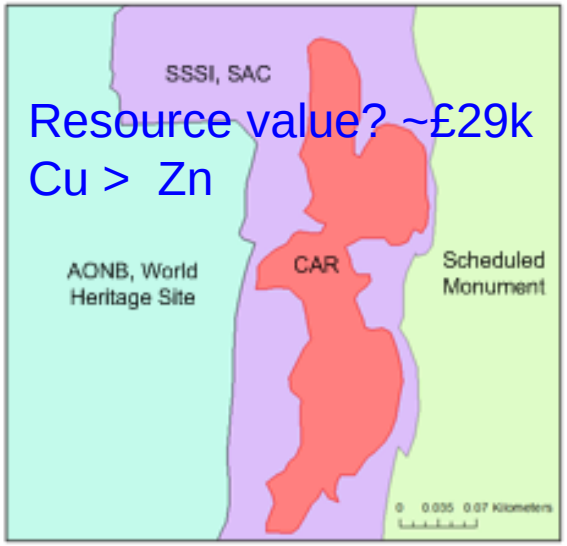
+ Estimates of volume (conservative)
+ Estimates of value /kg
= Estimates of resource (order of magnitude)











Decision support…..

- Selection strategy for optimising resource value a non-trivial problem multi-criteria decision support framework

Environmental	Economic	Social	Technical
Ecological receptors	Capital Cost	Public acceptance	Feasibility
Human receptors	Operating Costs	Cultural receptors	Infrastructure
Emissions to Water	Value of resource	Amenity use	Safety
Emissions to air	Land values	Health impacts	
Impacts on unique fauna/flora habitats	Reduced financial liability / risk	Nuisance	
Impact on landscape		Employment	

Case Study Conclusions

- Several mine wastes investigated contain metals (Cu, Pb and Sn) at concentrations close to or greater than typical minimum ore grade;
- Several mine wastes investigated contain pollutant metals (Cr, Ni, Zn, As, Cd, Pb) at concentrations exceeding Soil Guideline Values; and
- Most sites have historical significance, rare species assemblages or geological characteristics which may limit the potential recovery.
- Unlikely that economic gain of extracting valuable metals will constitute a sole driver for action.
- Instead this value could be considered as useful to offset site rehabilitation costs.

Future avenues of research - Technology

- (i) In situ conversion of wastes to high-value products
- (ii) The application of new metallurgical approaches that are highly selective to the target metals.
- (iii) Novel technologies for the manipulation of biogeochemical environments within waste repositories to achieve dissolution of target species
- (iv) Novel technologies for controlling flow in materials of low hydraulic conductivity

Acknowledgments

- Co-investigators on the various projects covered
- and the support given by NERC

- Related Papers:

Crane, R.A., Sinnett, D.E., Cleall, P.J., and Sapsford, D.J., 2016 "Physicochemical composition of wastes and co-located landscape designations at legacy mine sites in south west England and Wales: implications on resource potential" In press in *Resources, Conservation & Recycling*

Sapsford, D.J., Cleall, P.J., and Harbottle 2016 "In situ resource recovery from waste repositories: exploring the potential for mobilisation and capture of metals from anthropogenic ores" Submitted to Journal of Sustainable Metallurgy

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