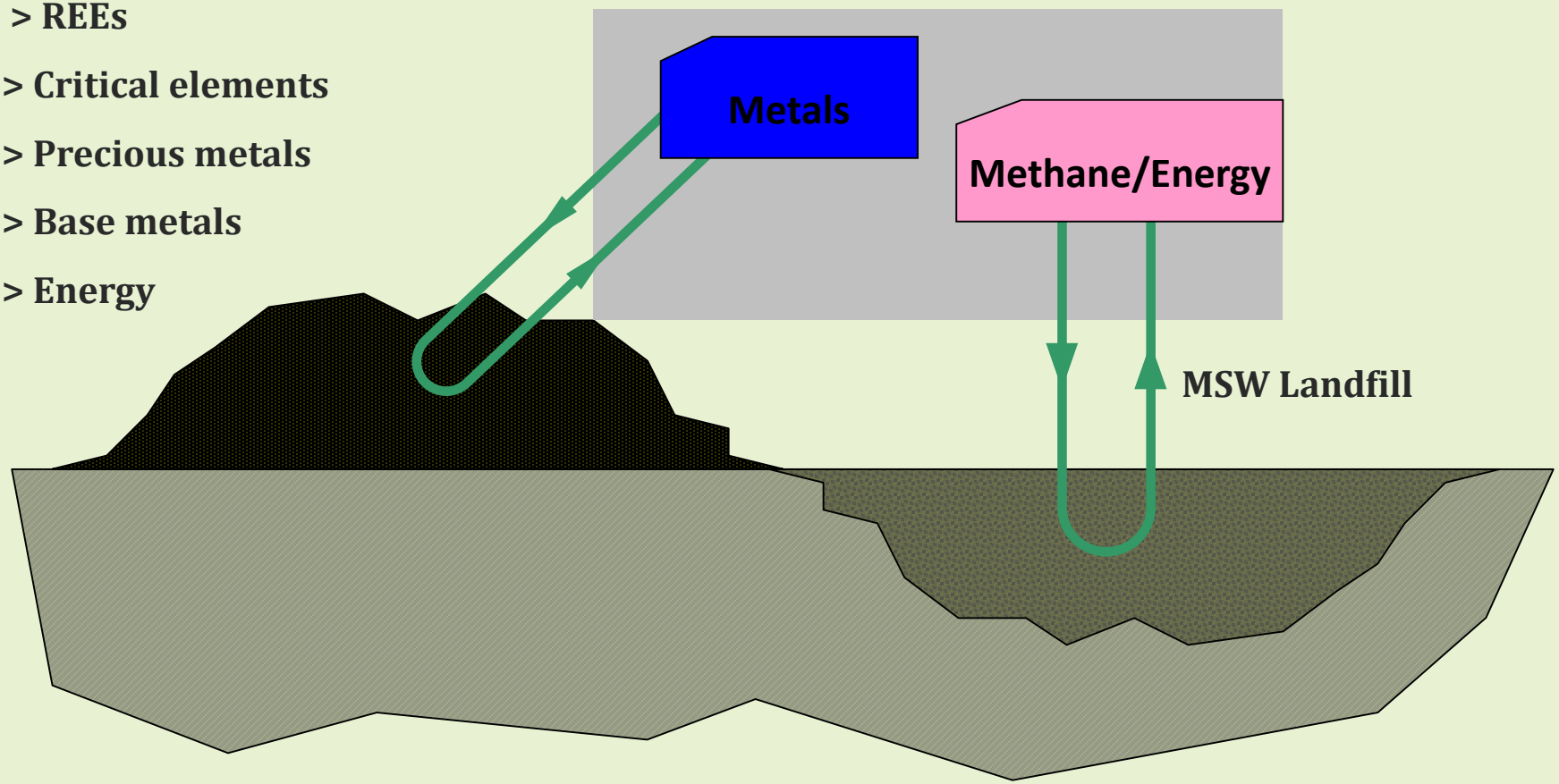
INSPIRE: IN Situ Processes In Resource Extraction from Waste Repositories

Dr Devin Sapsford, Dr Peter Cleall, Dr Michael Harbottle, Dr Talib Mahdi, Prof Andy Weightman, Prof Katie Williams, Dr Danielle Sinnett, Prof Tim Bugg, Dr Andy Clark, Dr Stefan Bon

In situ recovery of resources from waste repositories – can we mobilise and recover resources without "dig and process"

> REEs
> Critical elements
> Precious metals
> Base metals
> Energy



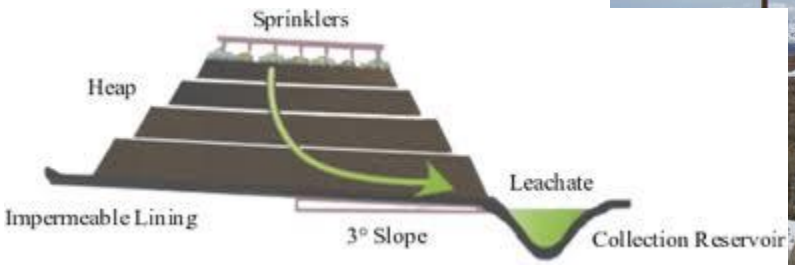
[1] MOBILISE → [2] FLOW PHENOMENA THROUGH COMPLEX MEDIA → [3] SELECTIVE RECOVERY OF RESOURCES

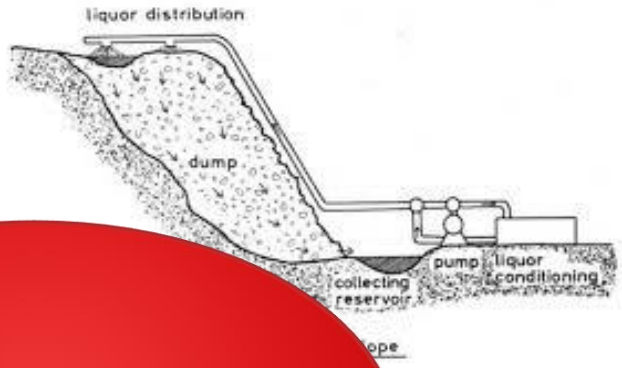
In situ leaching

Dump leaching

Stope leaching

Heap leaching





Allows for economic recovery of Cu, Ni, U, Au, Ag from low grade ores

"In situ resource recovery from waste repositories: exploring the potential for mobilisation and capture of metals from anthropogenic ores."
***accepted*: Journal Sustainable Metallurgy.**

- Ore Processing Residues
- Coal and incineration process fly ash and bottom ash
- Mine wastes
- Steel-making dusts
- Dredged Sediments
- Landfill soils

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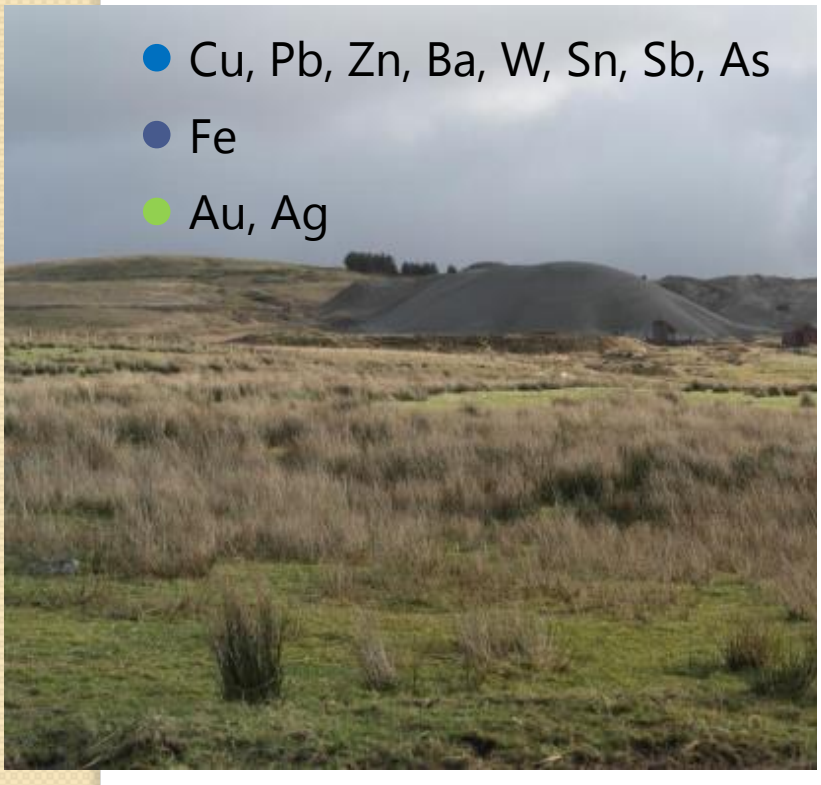
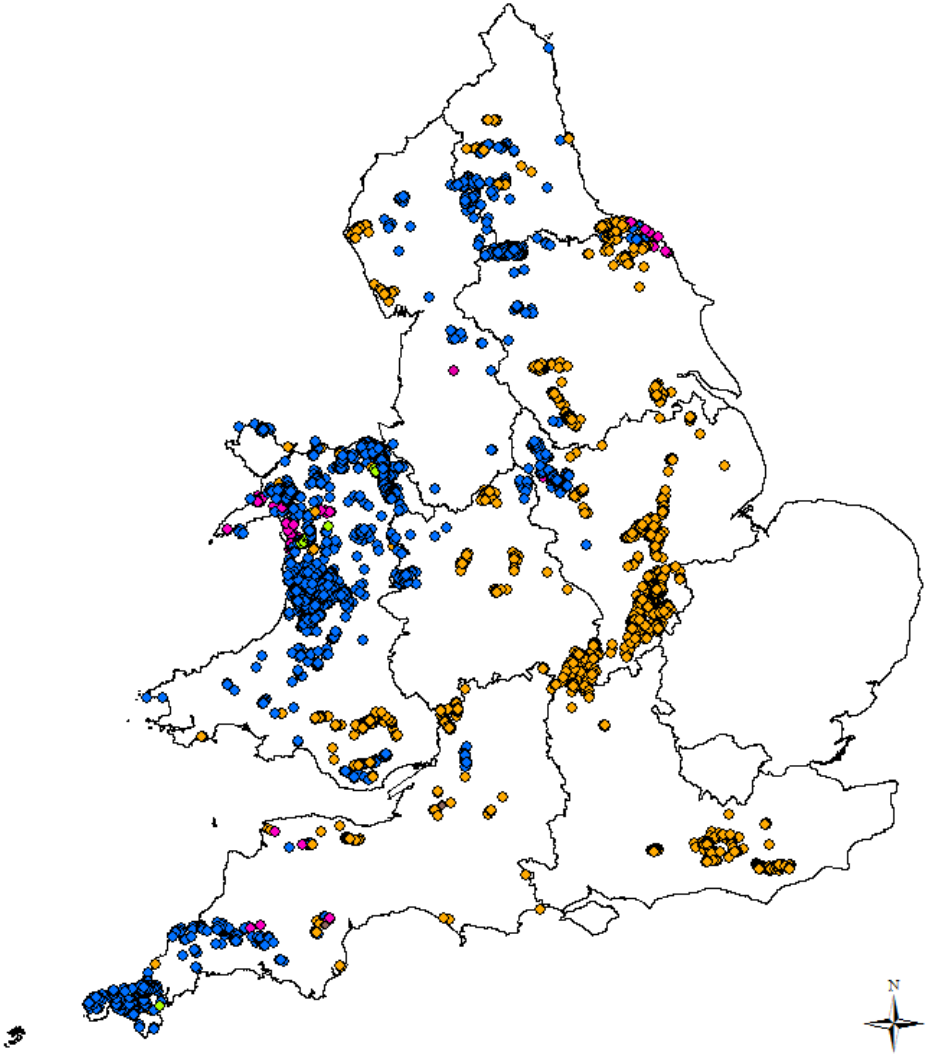
In-situ processes in resource recovery from waste repositories

Metal mine sites in England and Wales

8239 closed metalliferous mine sites in England and Wales

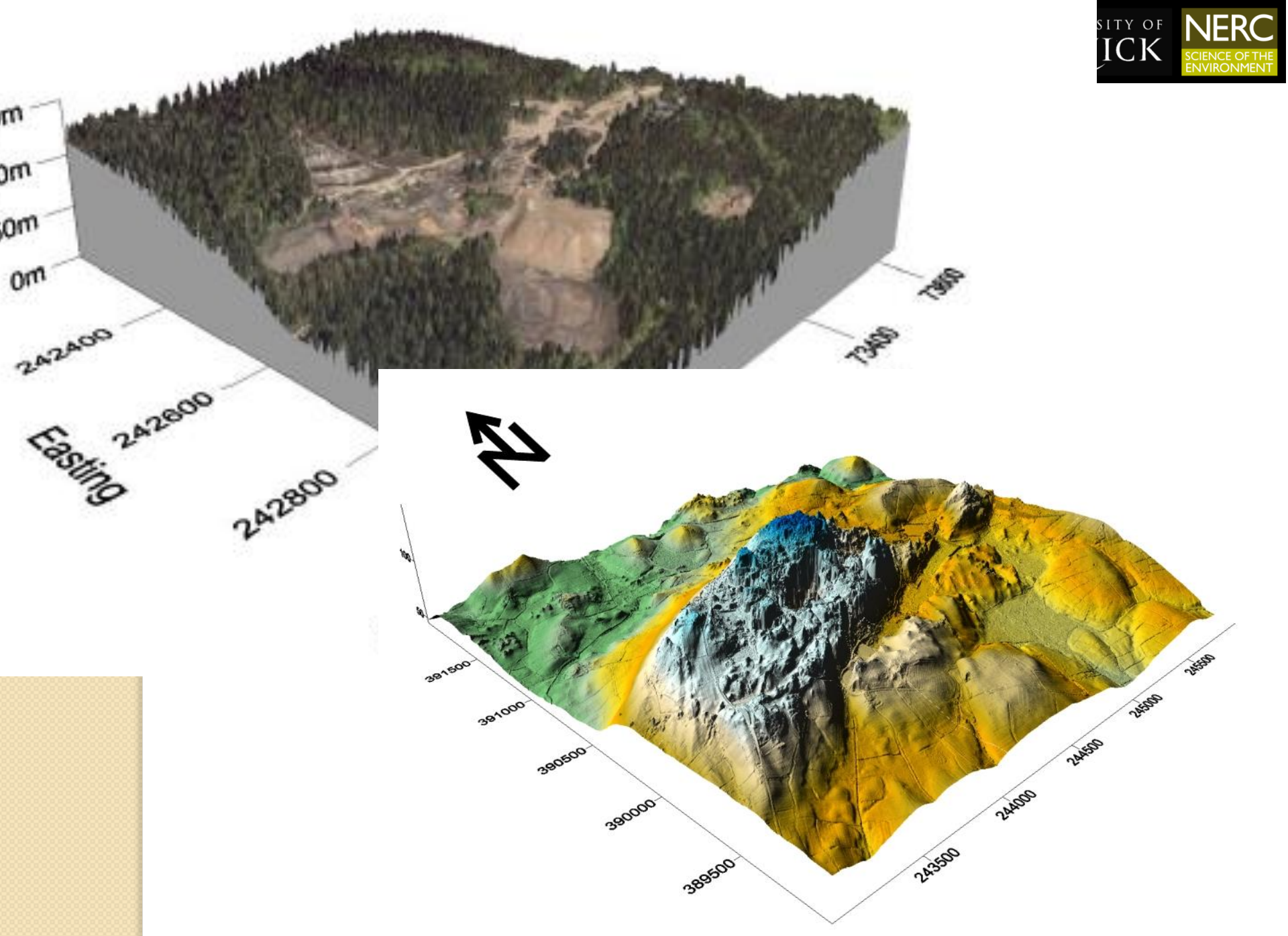




Maps courtesy of Dr Danielle Sinnett, Unversity of the West of England, UK

Case study sites – metal mine sites – what's their resource potential?

Waste volume determination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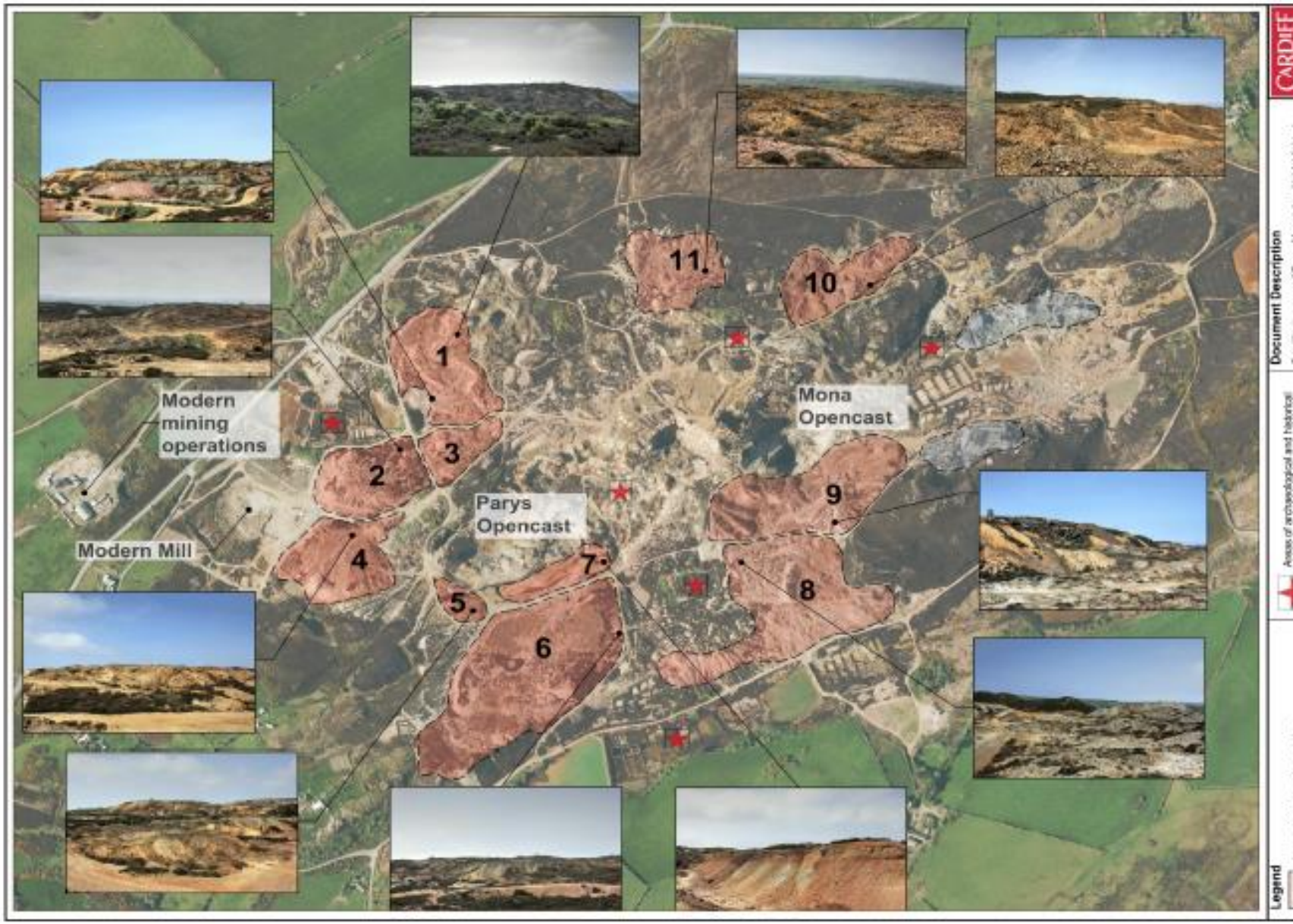
Modern mining operations
Modern Mill
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Mona Opencast
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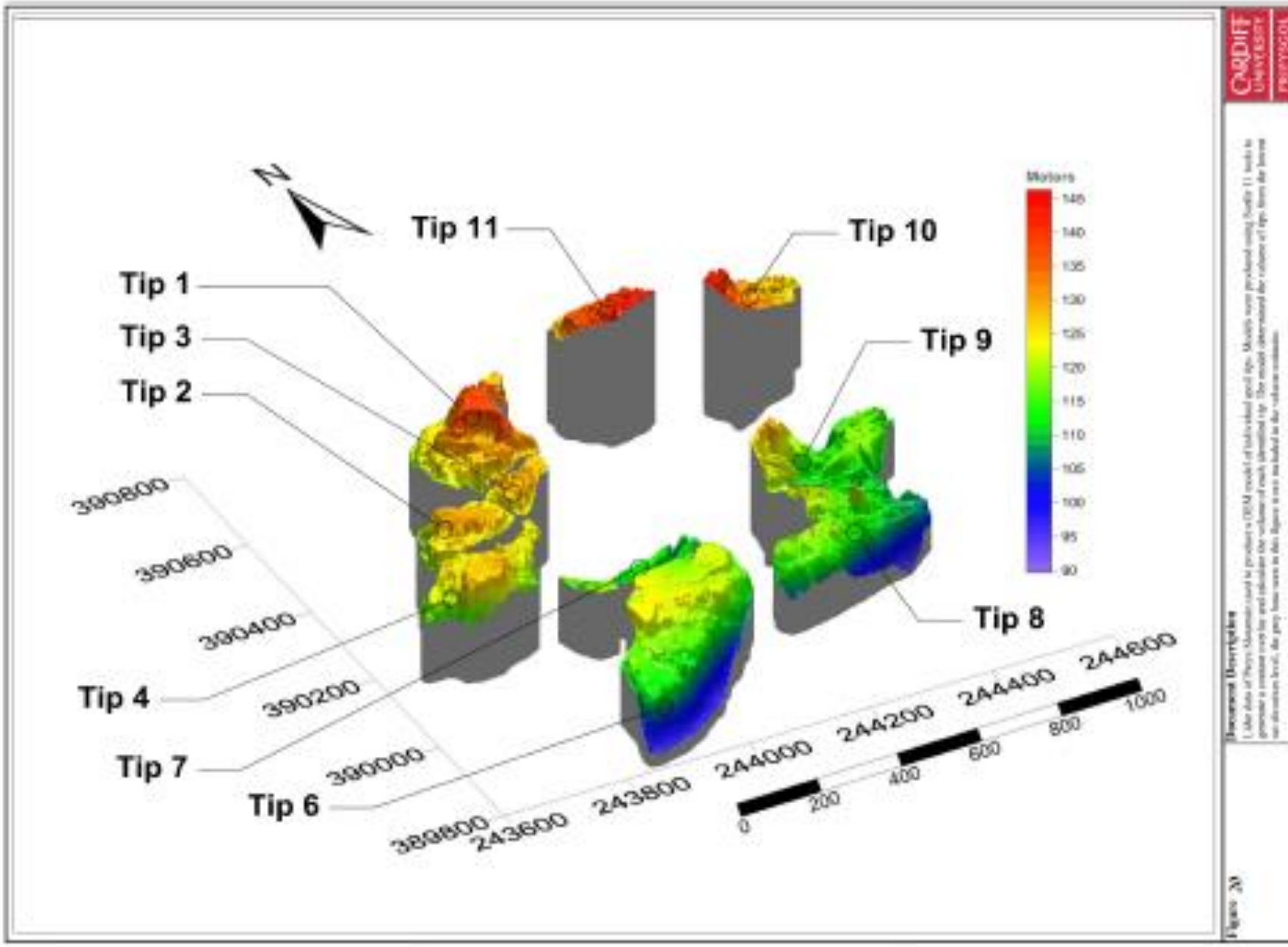
Document Description
Legend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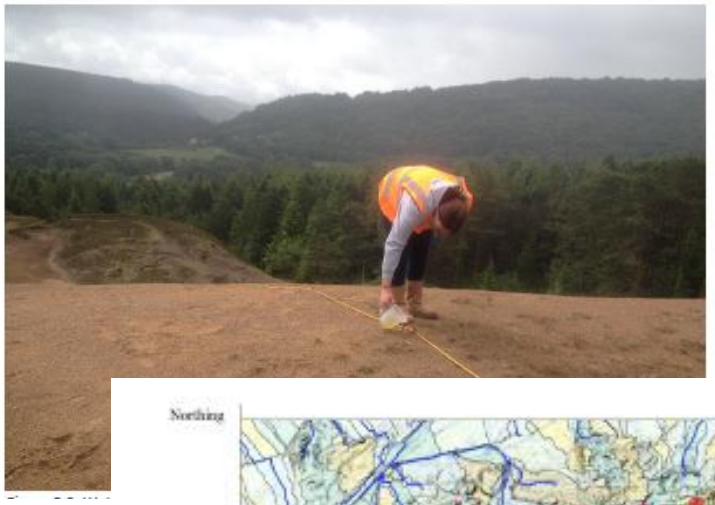
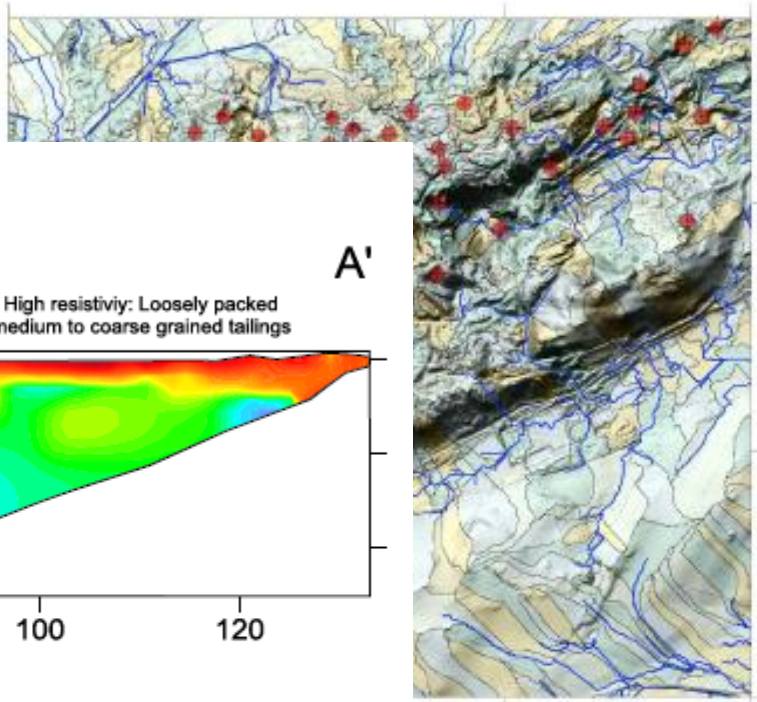
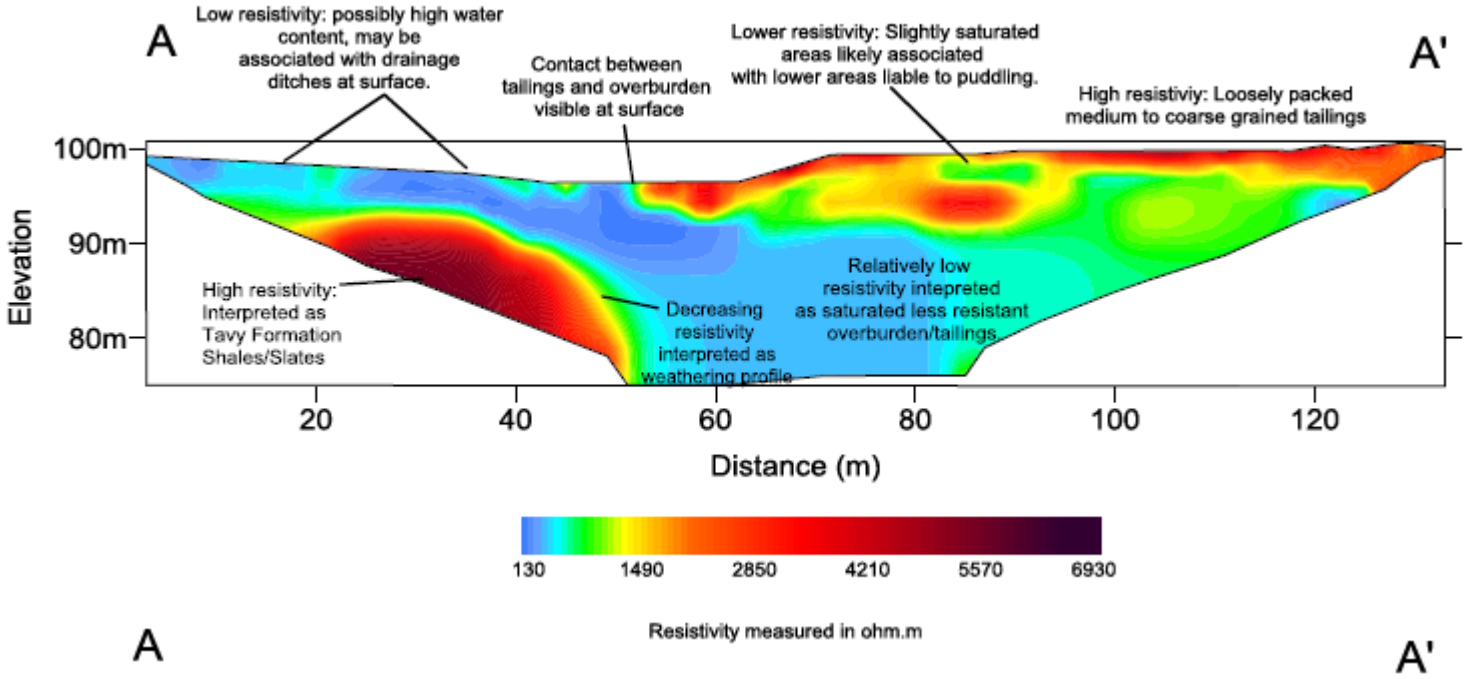
In-situ processes in resource recovery from waste repositories







Composition of wastes

- REE difficult!

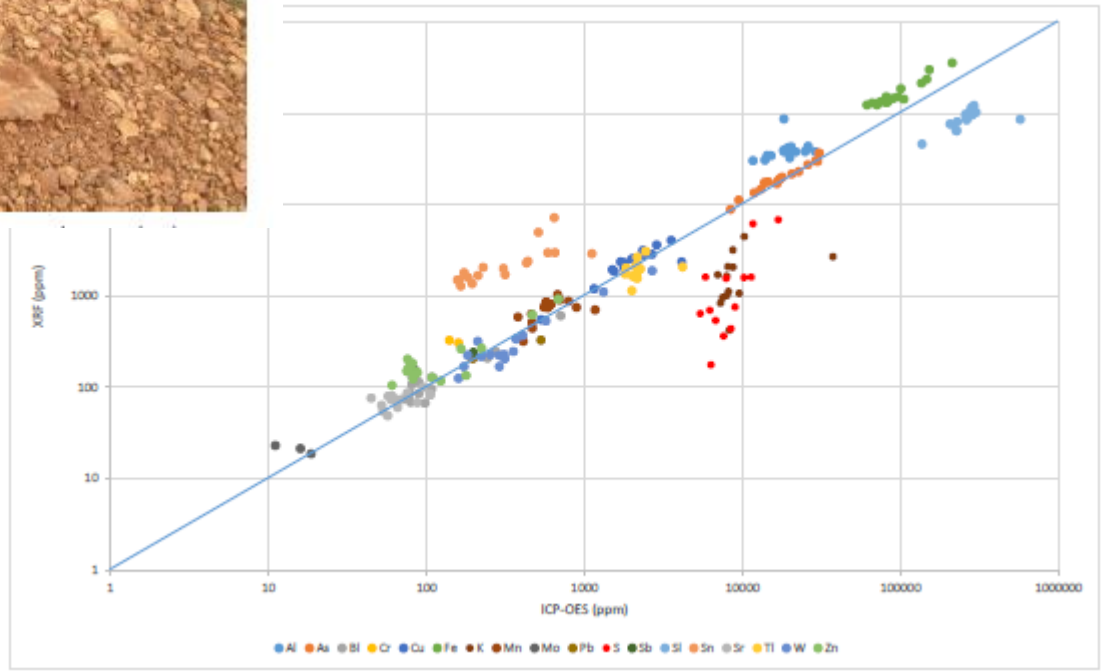
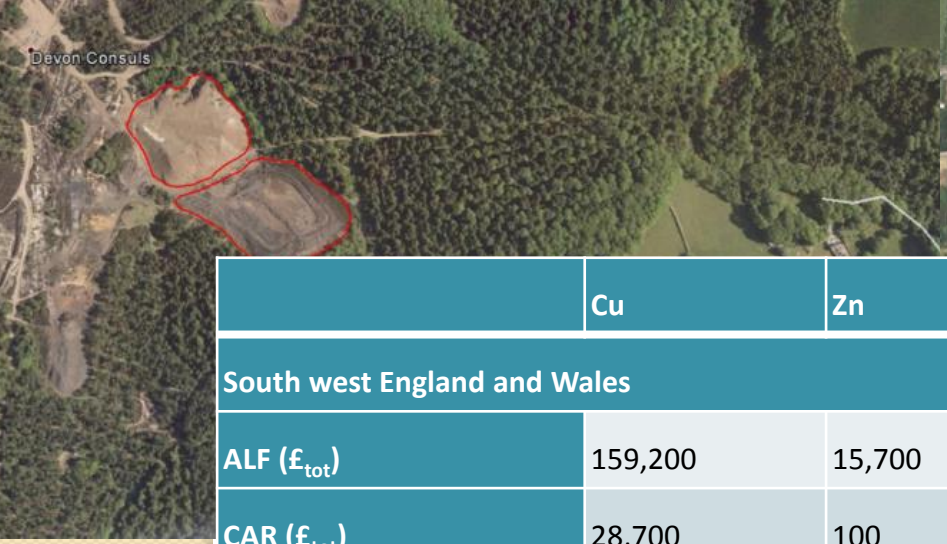


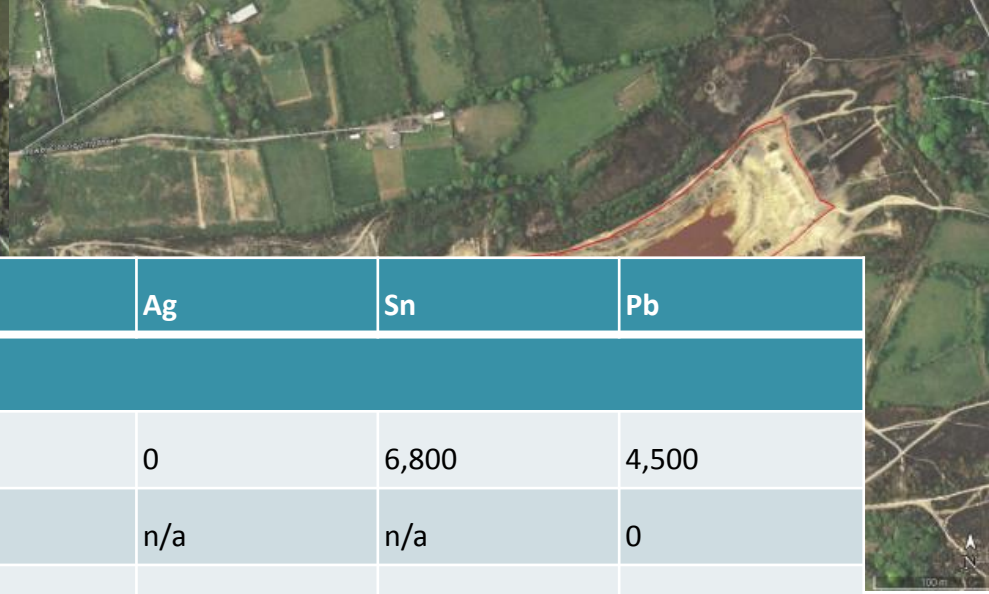
Figure 7.4: Scatter graph comparing results of ex-situ XRF and ICP-OES on paired samples

Chemical, biological and mineralogical characterisation of mine waste from SW England and Wales

"Physicochemical composition of wastes and co-located landscape designations at legacy mine sites in south west England and Wales: Implications on resource potential"

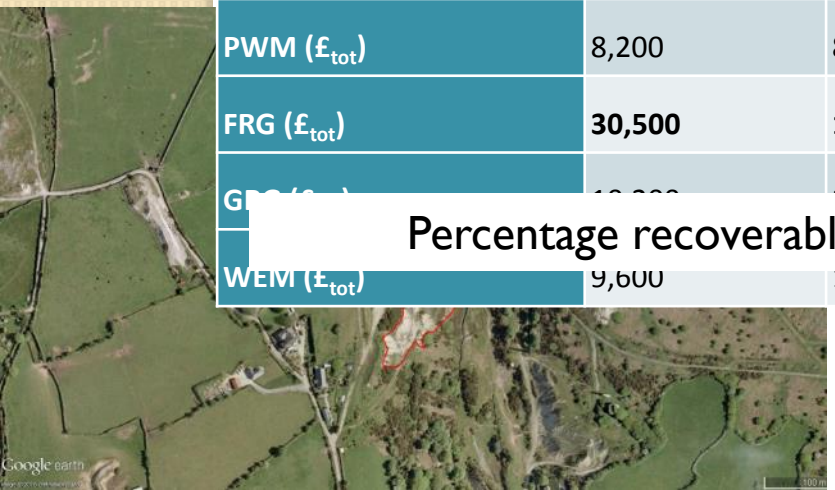
accepted in Resources, Recycling and Conservation on 08/08/16 (RECYCL3330, DOI: 10.1016/j.resconrec.2016.08.009)





	Cu	Zn	Ag	Sn	Pb
South west England and Wales					
ALF ($£_{tot}$)	159,200	15,700	0	6,800	4,500
CAR ($£_{tot}$)	28,700	100	n/a	n/a	0
CON ($£_{tot}$)	2,000	0	300	100	0
DGC ($£_{tot}$)	**1,657,600**	**33,600**	**0**	**887,000**	**20,700**
LEV ($£_{tot}$)	23,400	1,000	0	3,300	200
NAN ($£_{tot}$)	8,300	4,000	0	8,600	11,000
POL ($£_{tot}$)	18,200	1,600	0	0	0
PWM ($£_{tot}$)	8,200	800	0	23,200	400
FRG ($£_{tot}$)	**30,500**	**198,900**	**552,400**	0	**1,521,300**
GD[illegible]					
WEM ($£_{tot}$)	9,600	104,700	0	0	410,600

Percentage recoverable in 1M sulphuric acid also determined



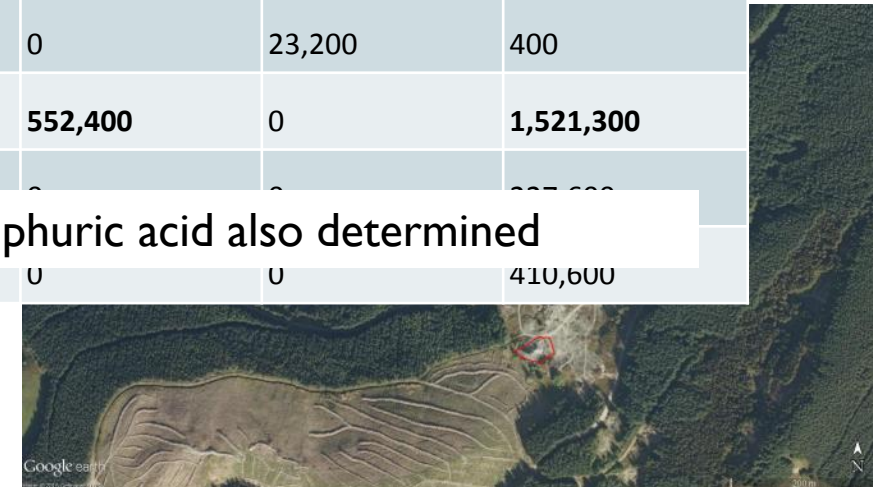
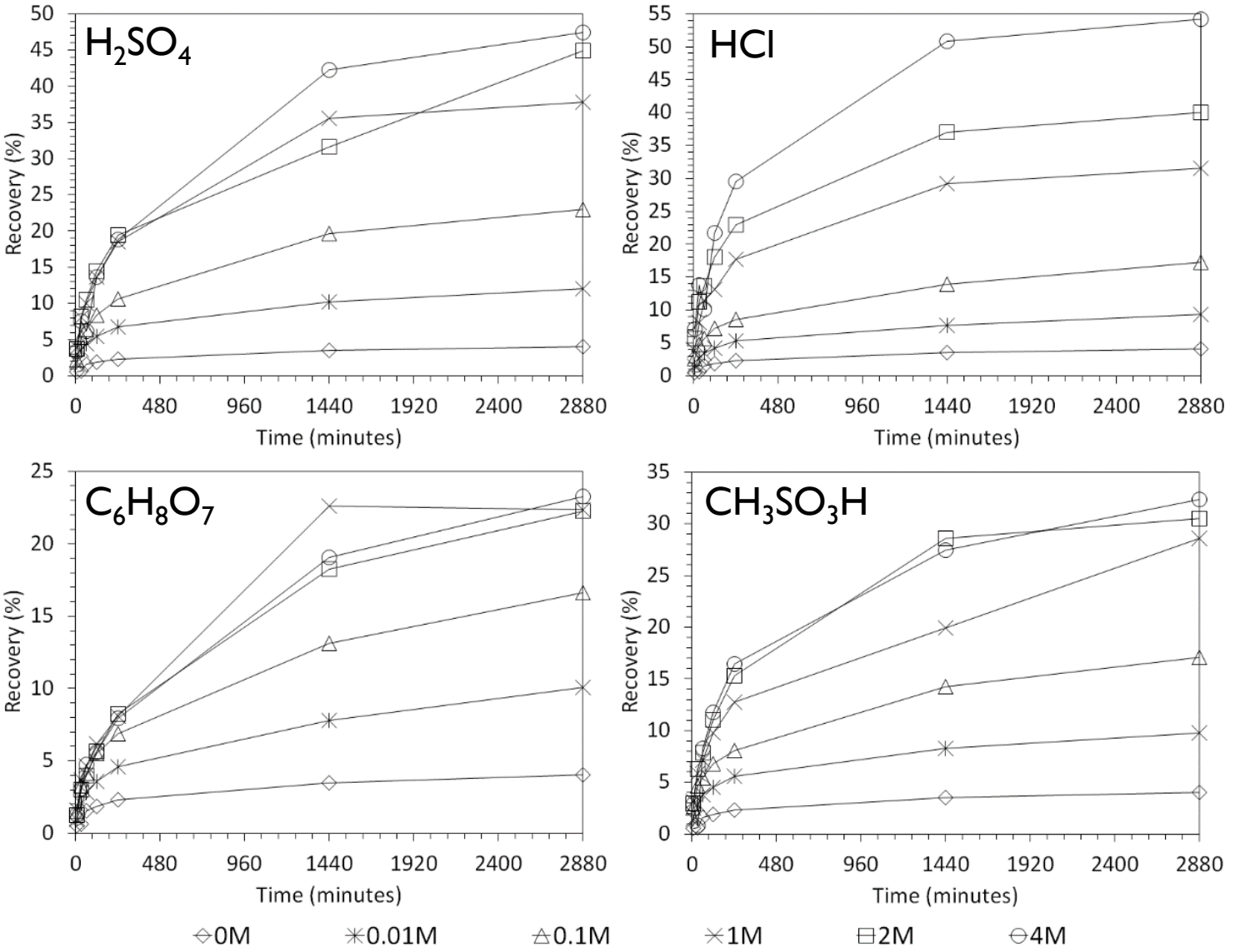


Table 3. Metal concentration data for composite samples from all sites where green cells indicate concentrations above screening levels for ecological risk[1]; orange indicate those above guideline levels for human health risk[2,3] and red indicate those above both.

	Li	Na	Mg	Al	K	Ca	Ti	Cr[1,2]	Mn	Fe	Ni[1,3]	Cu[1]	Zn[1]	As[1,2]	Ag	Cd[1,2]	Sn	Pb[1,2]
South west England																		
ALF (wt. %)	0.0233	0.2297	1.4343	5.5579	1.2753	0.1888	0.3367	0.0209	0.2353	10.5592	0.0041	0.1540	0.0426	0.0935	<DL	0.0013	0.0019	0.0120
CAR (wt. %)	0.0132	0.5295	0.3014	6.2791	4.1266	0.8129	0.1141	0.013	0.0474	3.3928	<DL	0.2345	0.0078	0.1219	<DL	0.0002	<DL	0.0023
CON (wt. %)	0.0157	0.3451	0.593	5.1893	0.7046	0.1272	0.2100	0.0108	0.1411	13.6919	0.0016	1.7572	0.0916	0.8293	0.0023	0.0019	0.0238	0.0587
DGC (wt. %)	0.0135	0.4312	0.5295	4.6035	0.8871	1.1426	0.2207	0.0315	0.0610	9.9893	0.0019	0.1833	0.0101	1.9176	<DL	0.0012	0.0290	0.0067
LEV (wt. %)	0.0152	0.3721	1.7030	6.6606	1.9049	0.4451	0.5196	0.0128	0.1433	15.2487	0.0042	0.5168	0.0646	0.2543	<DL	0.0018	0.0216	0.0099
NAN (wt. %)	0.0249	0.3660	0.4250	7.8022	2.2552	0.0806	0.3049	0.0147	0.0354	3.5632	0.0003	0.0126	0.0170	0.0405	<DL	0.0002	0.0039	0.0466
POL (wt. %)	0.0243	0.4456	0.2455	7.2796	3.9765	2.8003	0.1231	0.0105	0.0549	2.7428	0.0004	0.0549	0.0131	0.1059	<DL	0.0001	0.0084	<DL
PWM (wt. %)	0.0119	0.5053	0.5990	6.2204	1.1573	0.0897	0.3126	0.0141	0.0628	6.9515	0.0019	0.0937	0.0254	1.5872	<DL	0.0008	0.0782	0.0120
WHM (wt. %)	0.0098	0.6279	0.6080	5.9665	0.6063	0.0949	0.2704	0.0116	0.0396	11.4857	0.0020	0.0446	0.0680	0.1823	<DL	0.0014	0.0300	0.0386
Wales																		
EGM (wt. %)	0.0138	0.7943	0.9825	7.8934	2.3115	0.4153	0.4998	0.0098	0.0986	4.6388	0.0035	0.2406	0.2103	<DL	<DL	0.0007	<DL	2.3602
FRN (wt. %)	0.0124	0.494	0.3235	2.8913	0.8196	0.1054	0.1758	0.0081	0.017	2.4758	0.0010	0.0337	0.6155	<DL	0.006	0.0016	<DL	4.6662
GRG (wt. %)	0.0145	0.9206	1.0651	8.9666	2.4768	0.5315	0.5331	0.0114	0.1329	4.9254	0.0049	0.0210	0.1948	<DL	<DL	0.0007	<DL	1.3009
PYM (wt. %)	0.0013	0.5467	0.1661	2.7089	1.3942	0.134	0.1600	0.0225	0.0544	27.3302	0.0091	0.9191	0.1494	0.1369	0.0034	0.0052	0.0569	0.9124
WEM (wt. %)	0.0151	0.635	0.5845	6.2005	1.6870	0.0975	0.3769	0.0141	0.0416	3.3651	0.0019	0.0059	0.1797	<DL	<DL	0.0006	<DL	0.6984

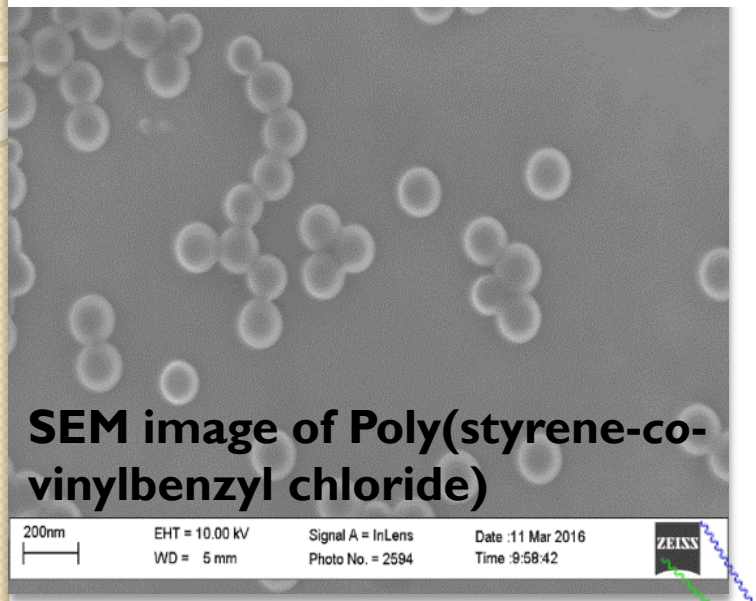
Copper Recovery (48 hrs)



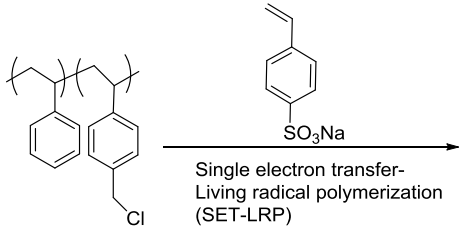
L:S =10

What can we use to leach the metals out?

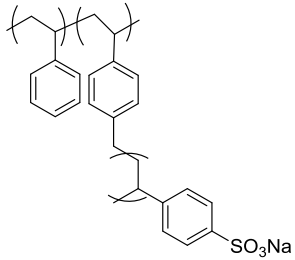
Engineered nanoparticles



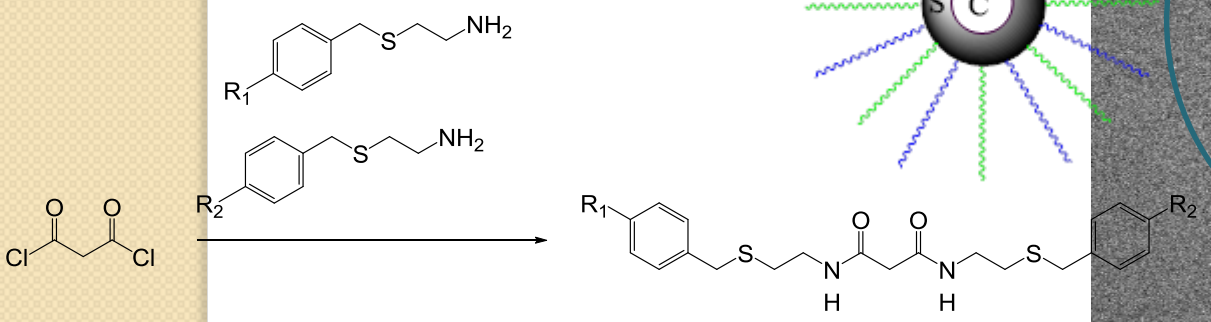
SEM image of Poly(styrene-*co*-vinylbenzyl chloride)



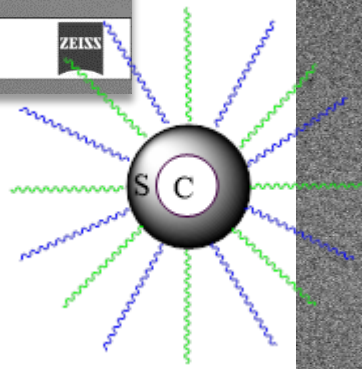
Poly(styrene-*co*-vinylbenzyl chloride) (Poly(St-*co*-vbc))

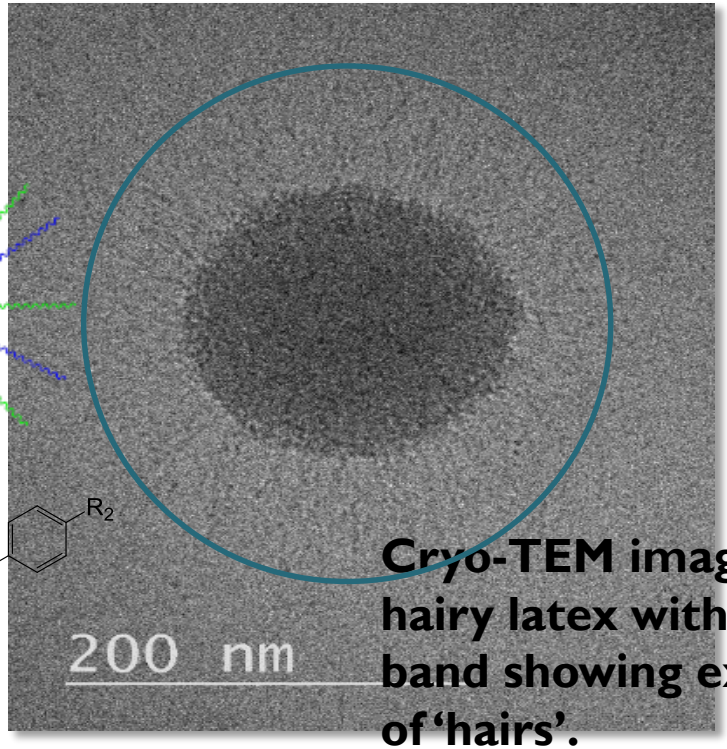


Poly(styrene-*co*-vinylbenzyl chloride)-*g*-poly(sodiumstyrene sulfonate) (Poly(St-*co*-vbc)-*g*-poly(NaSS)



Synthesis of analogue of Ag-selective ligand.

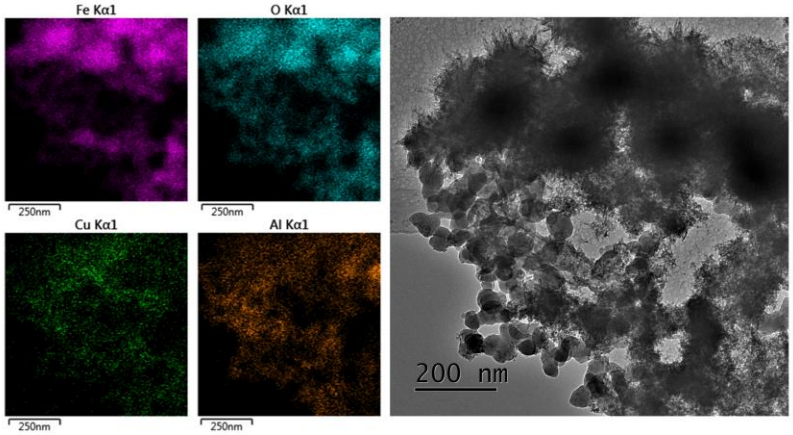


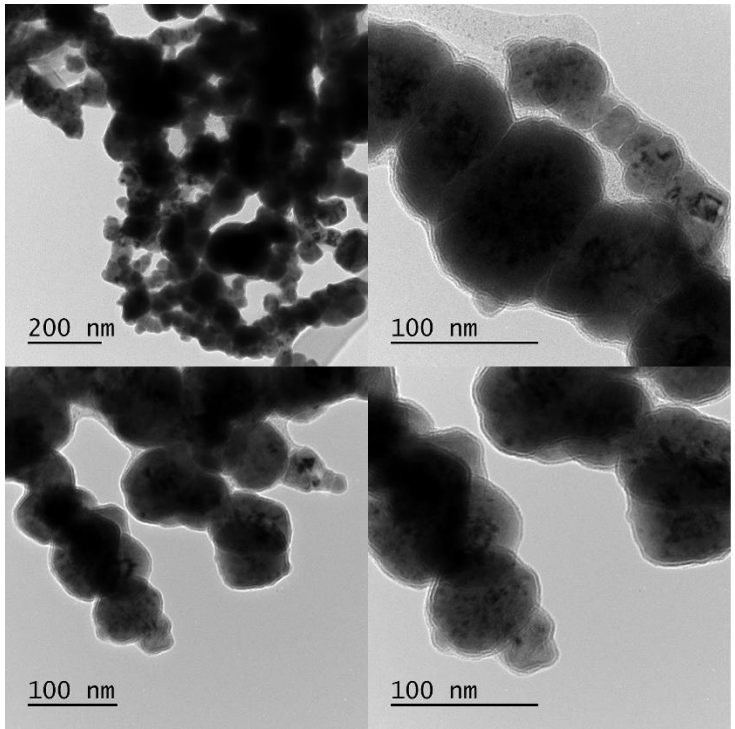


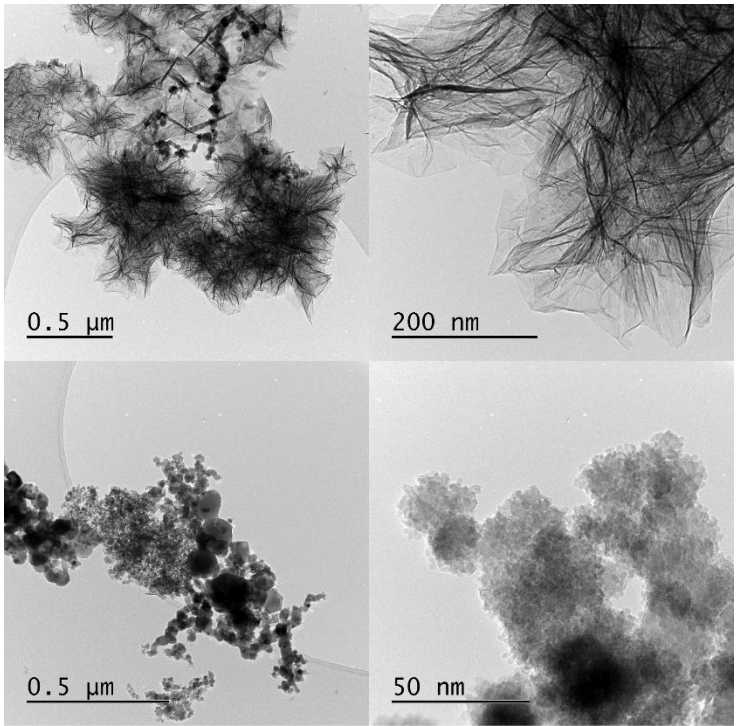
Cryo-TEM image of hairy latex with blue band showing extent of 'hairs'.

Use of nZVI for the selective recovery of metal and metalloids from metalliferous waste and mine water

- ✓ Mixture of Cu and Cu_2O (when Cl- is absent)
- ✓ Paratacamite (when Cl- is present)
- ✓ Ferrihydrite "needles"
- ✓ nZVI extremely selective for Al and Cu only from mine water



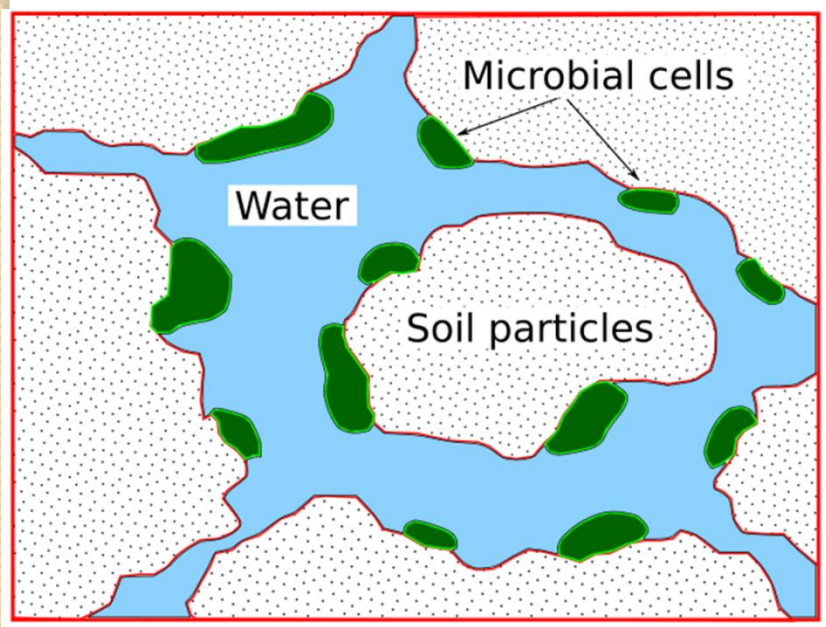




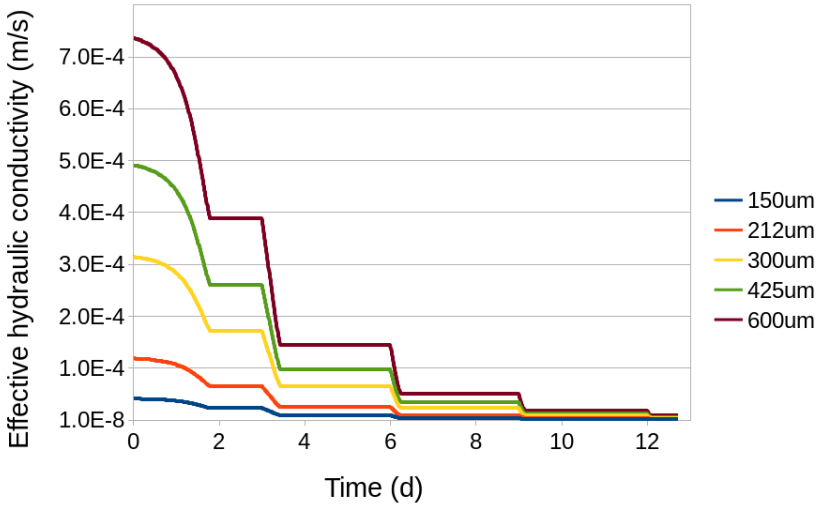
How can we control flow?

1. Bioclogging

Microbial activity in porous materials can produce by-products that are able to accumulate in the pores influencing in this way the transport of substances within the material and ultimately may impede the movement of fluids by pore clogging.



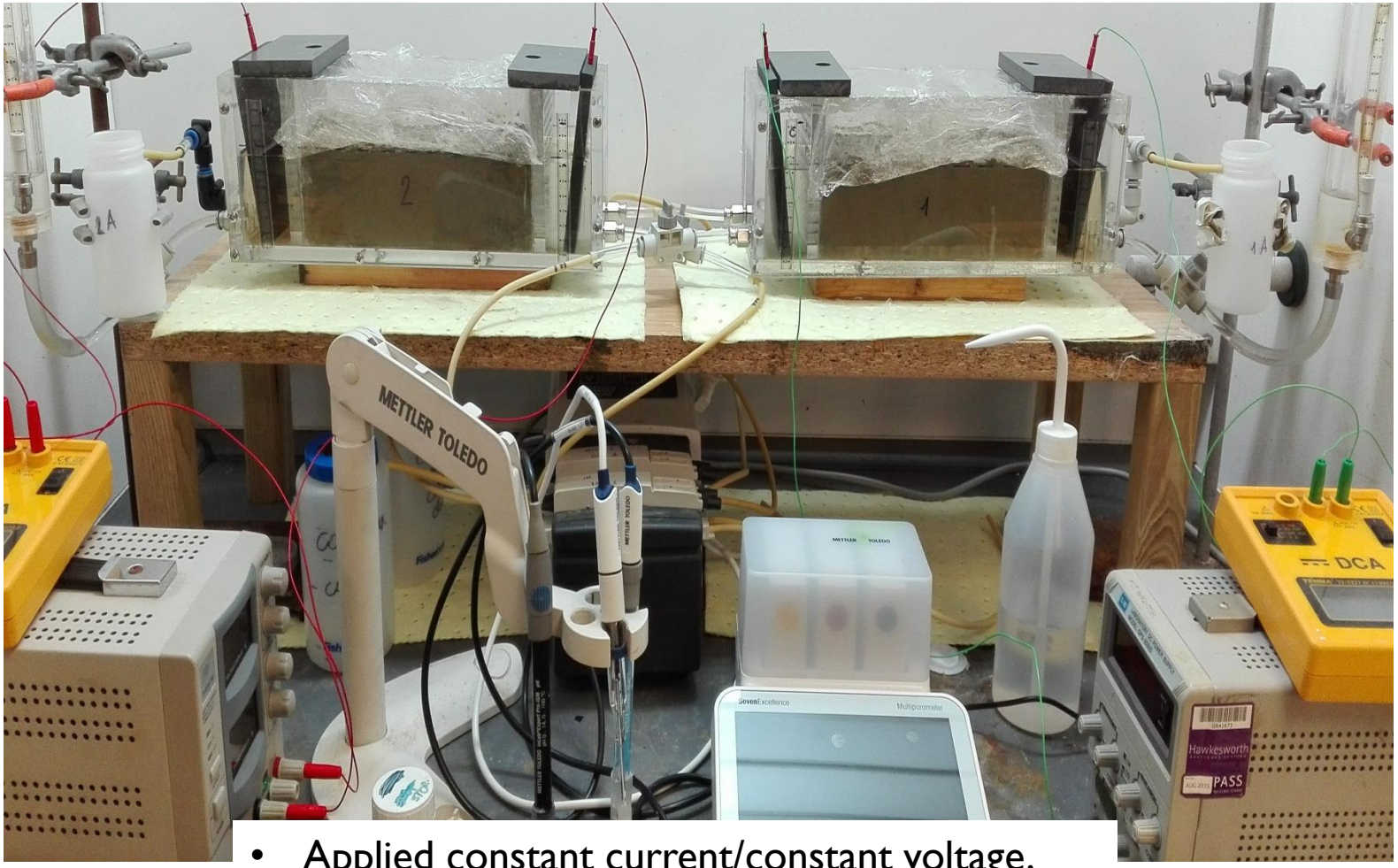
Soil domain partially colonized by microbial cells.



Measured decrease in hydraulic conductivity in soil domain

How can we control flow?

2. Electrokinetics

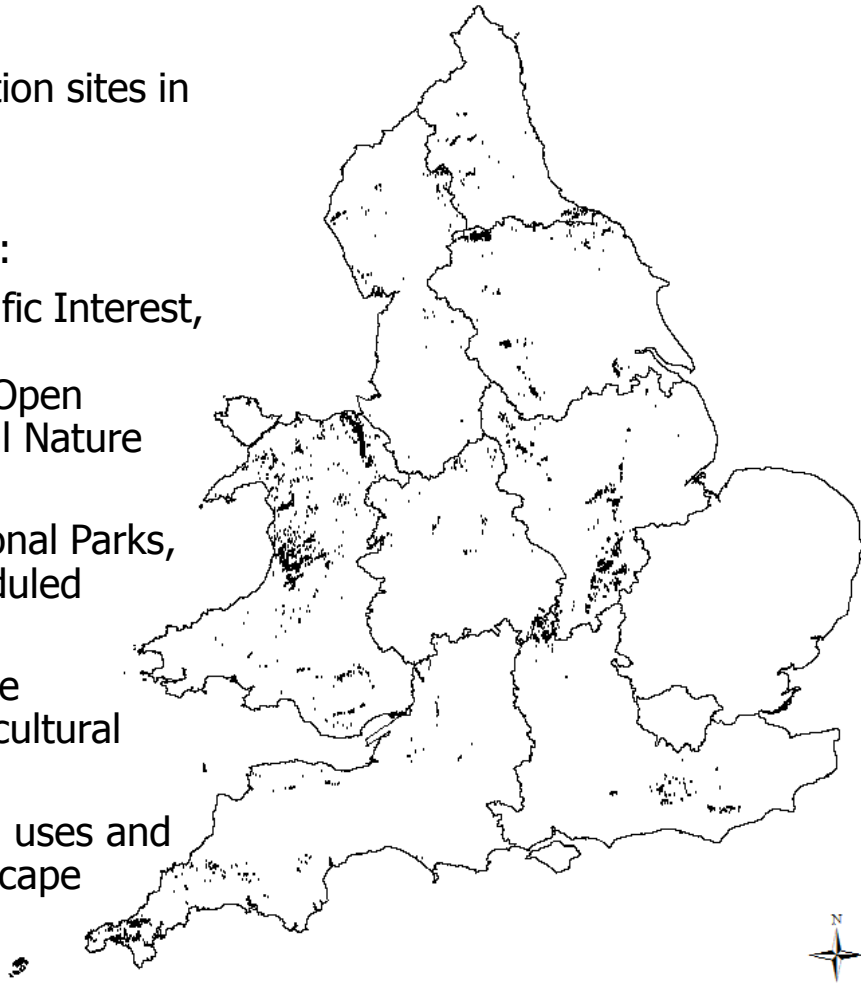


- Applied constant current/constant voltage.
- Two sets of compressed graphite electrodes

Economics is only one dimension of "value"...

Metalliferous mine sites

- BRITPITS: 128,337 non-active mineral extraction sites in England and 27,124 in Wales
- Historic Landfill database
- Combined with spatial data on land cover and:
  - Ancient Woodlands, Sites of Special Scientific Interest, Special Protection Areas, Special Areas of Conservation, Priority Habitats (England), Open Mosaic Habitats on PDL, National and Local Nature Reserves
  - Areas of Outstanding Natural Beauty, National Parks, Country Parks, World Heritage Sites, Scheduled Monuments, Parks and Gardens (England)
- Frequency and extent of co-location with these designations and land cover – ecological and cultural value
- Literature review on restoration practices, end uses and potential ecosystem, environmental and landscape services provided by such sites



Produced using BritPits database; Licence No. 2014/098BP ED
British Geological Survey NERC. All rights reserved.
Boundary data from UK Data Service http://census.edina.ac.uk.

0 20 40 80 Kilometers

Ecosystem and geosystem (dis)services

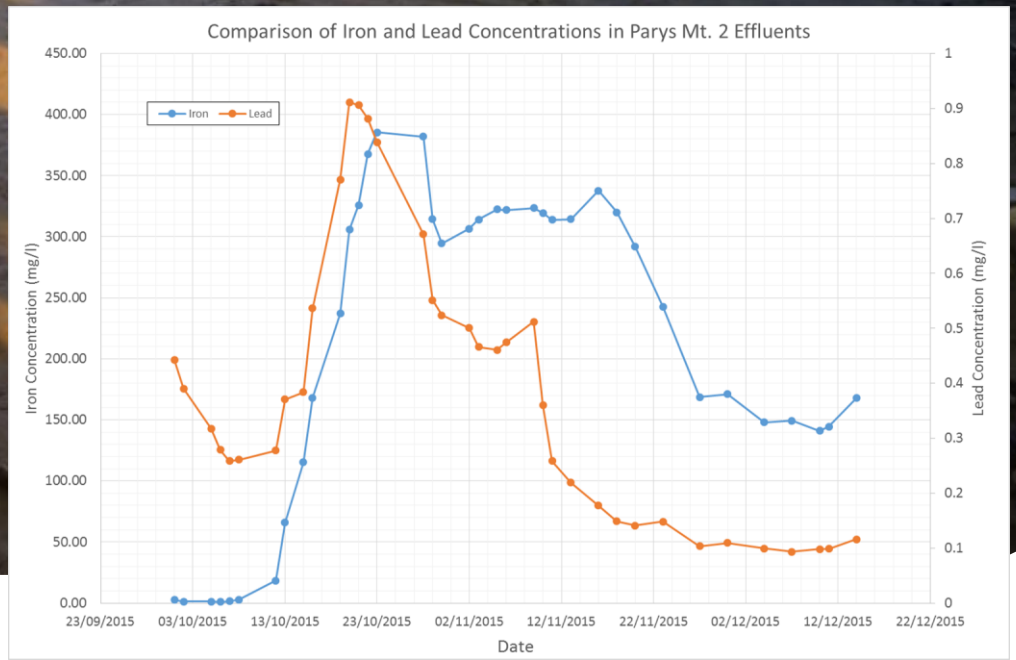
			Provisioning			Regulating						Cultural				
	Waste disposal	Wild species	Crops	Timber	Fresh water/Fish	Climate	Flood risk	Water quality	Pollination	Soil quality	Air quality	Env.l settings	Tourism	Education	Recreation	Heritage & place
Metalliferous mines		✓×	✓		×			×		×	×	✓	✓	✓	✓	✓×
Landfills	✓	✓	✓	✓		✓		×	✓		×	✓			✓	

- Next: testing with local communities and stakeholders e.g. On acceptability of different interventions and technologies

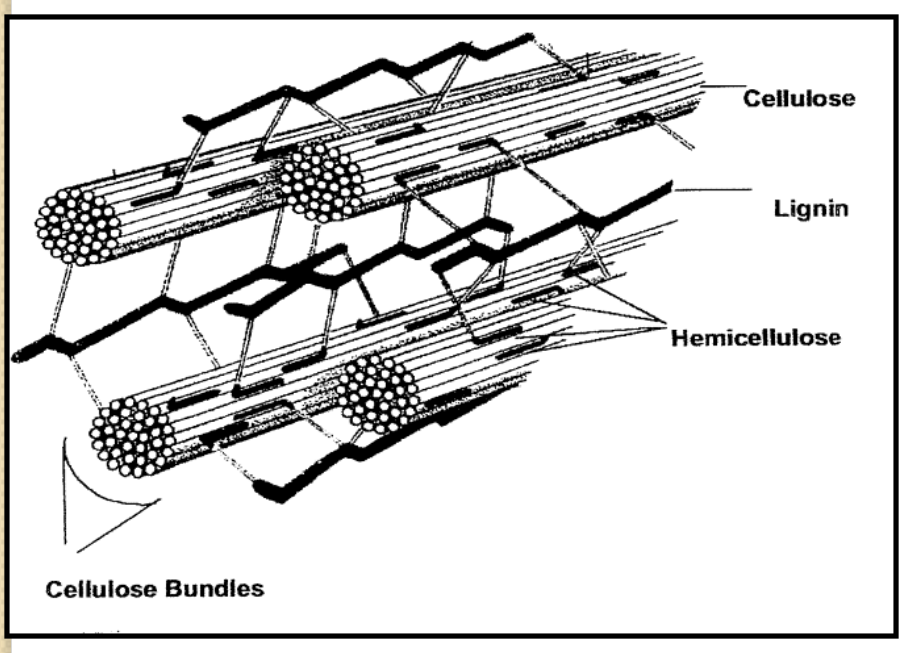
Microbial Wealth in wastes

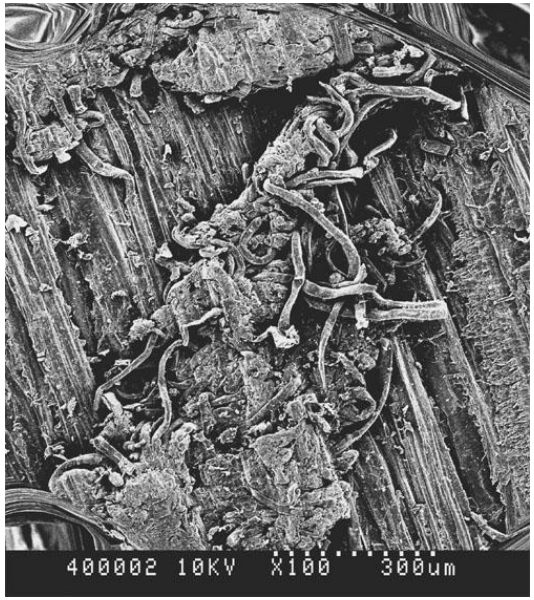
Micro-environmental services co-opted for resource recovery...

Iron oxide rich wastes



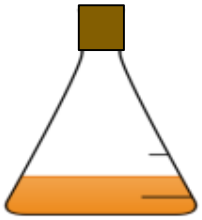
Microbial lignocellulose degradation and methanogenesis in landfills and waste systems



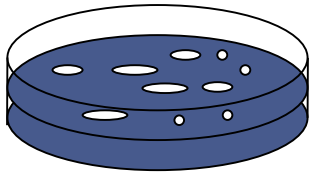


Screening for Novel Lignin Degrading Strains

Sampling

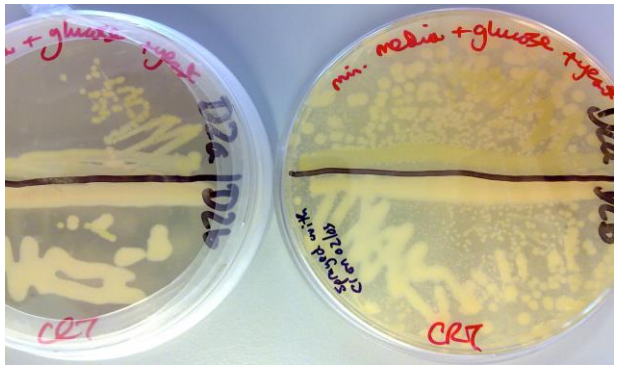


Culturing – selective medium



Plating

Nitrated lignin spray assay



Pure cultures

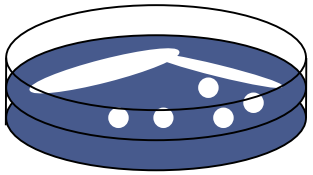
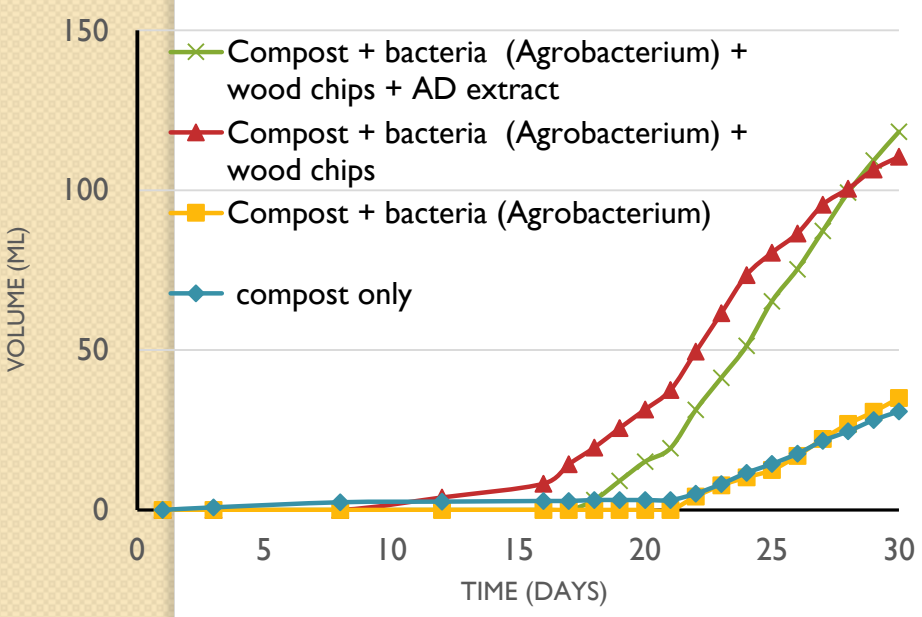
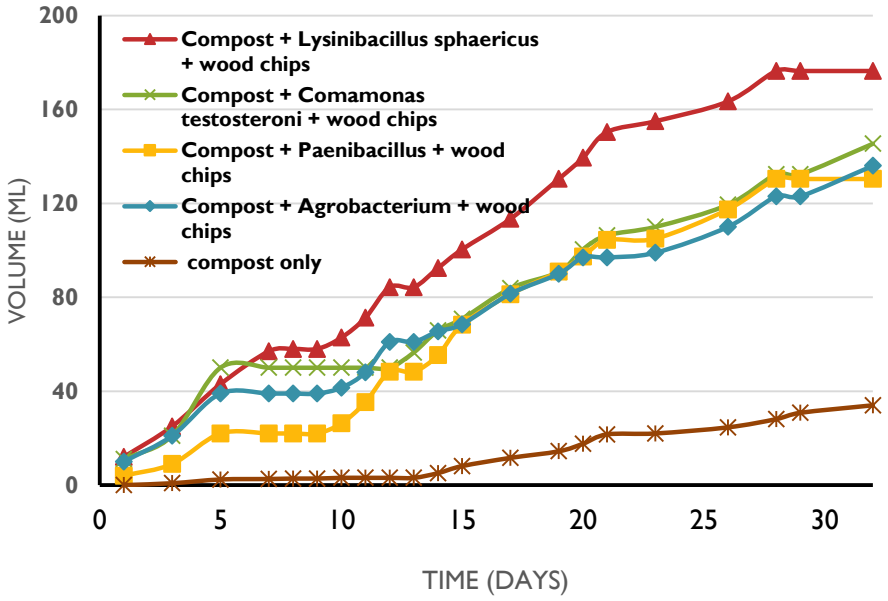


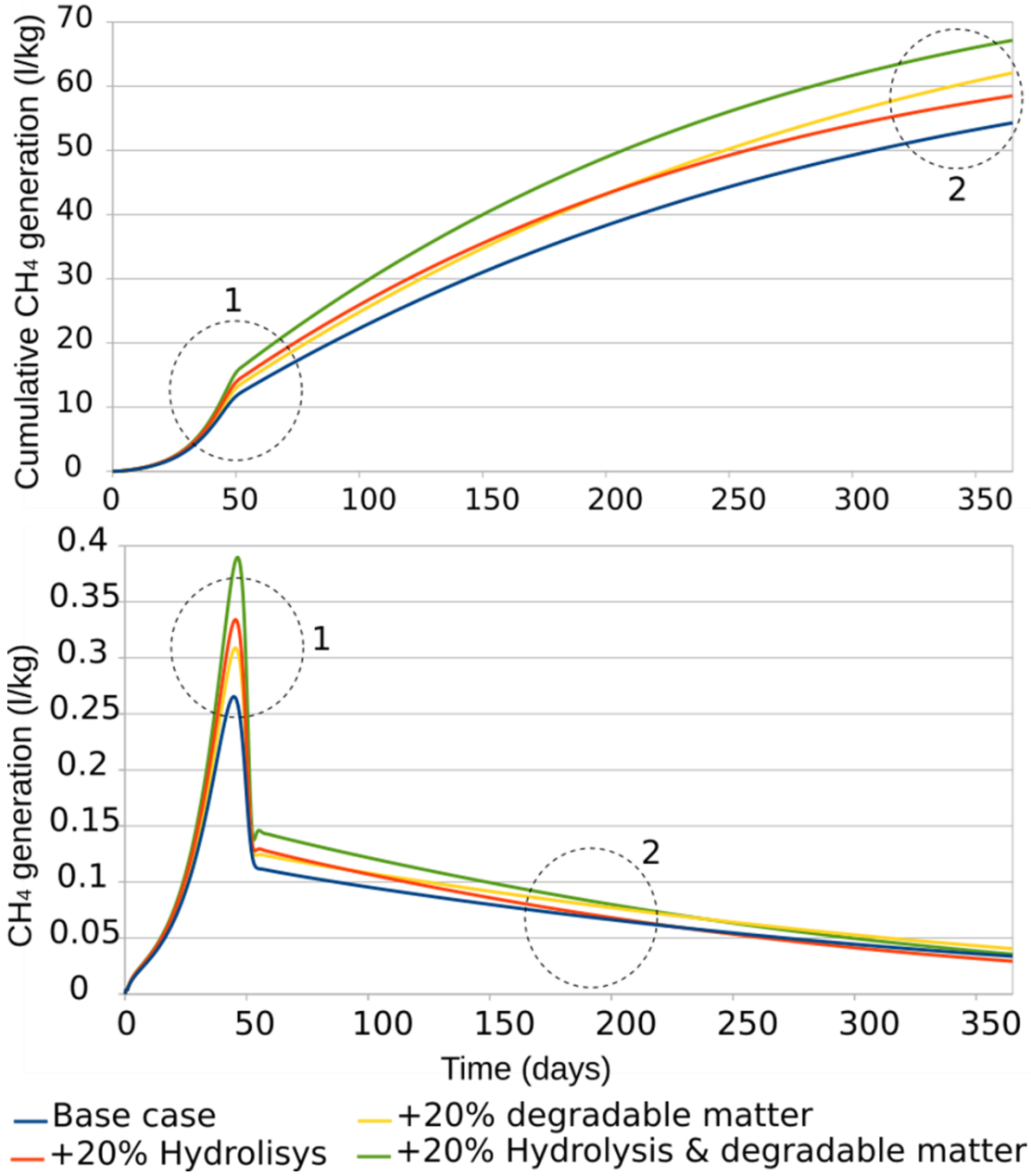
Plate assay

- Identification bacterial species (e.g.16S rRNA)
- Purify and identify extracellular enzymes
- Recombinant expression

Methanogenesis experiments

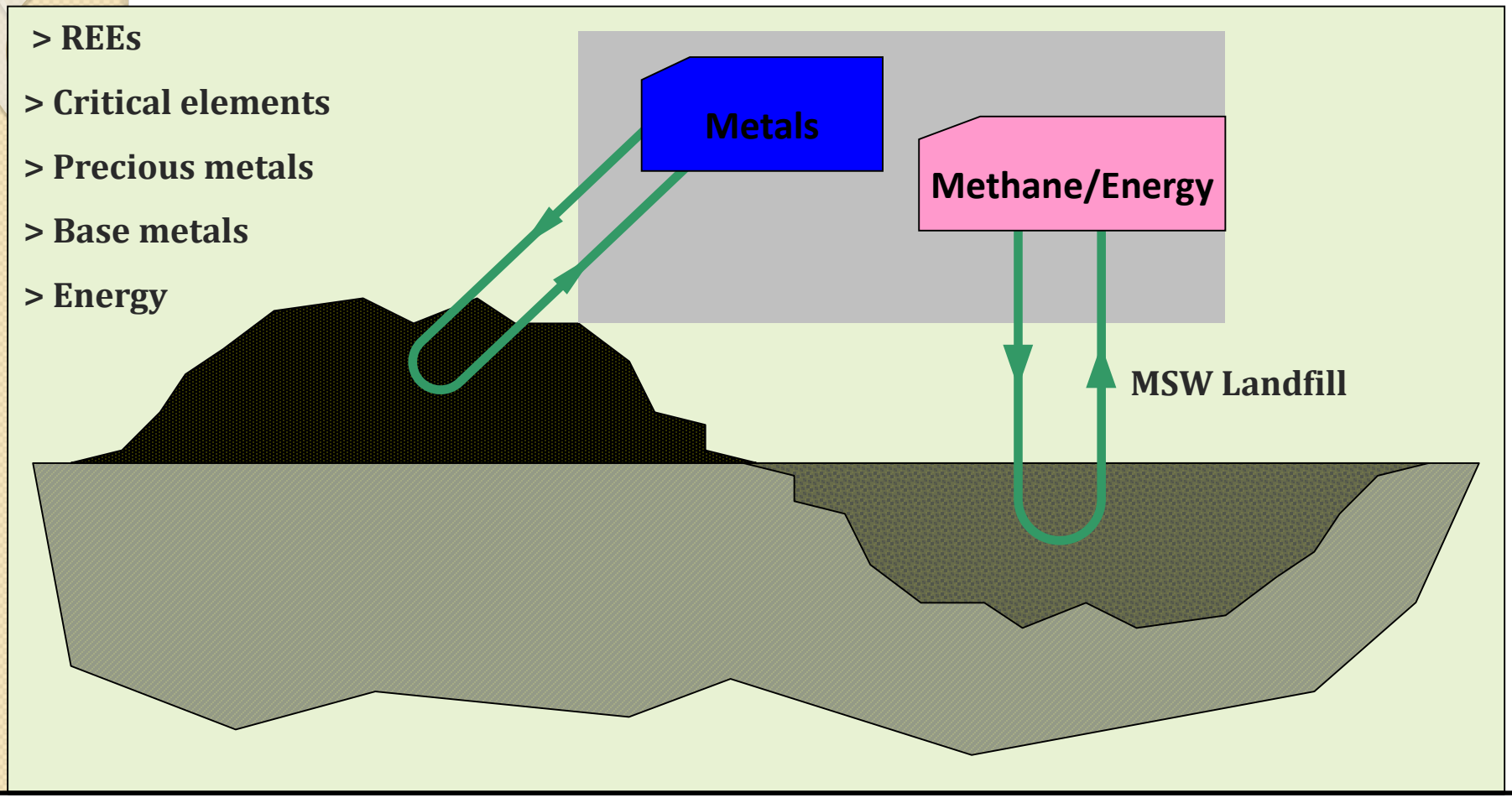






Methanogenesis modelling with enhanced lignocellulose degradation

Conclusions: Delivering environmental science and engineering



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



Thank you

Dr Devin Sapsford
Cardiff School of Engineering
Cardiff University