Opportunities in Urban Biomining from IT and Telecoms Equipment

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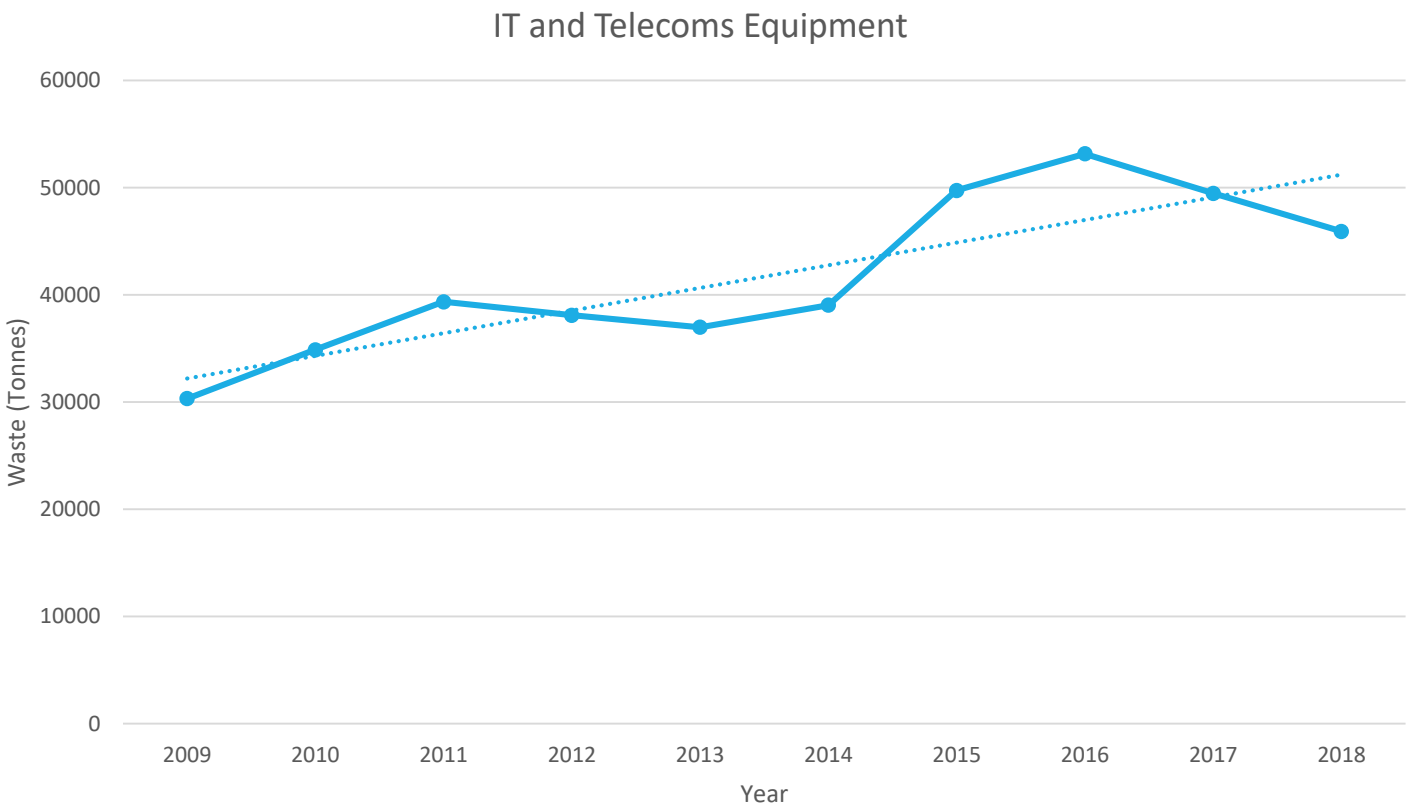
How much Waste?

Annually the UK produces on average

- 512,000 tonnes of WEEE
- 42,000 tonnes of Waste IT and Telecoms



(Environment Agency 2019)

What's in the Waste?

Metal	Ores (%) [a]	PCBs (%) [b]
Copper	0.5–3.0	12.0–29.0
Zinc	1.7–6.4	0.1–2.7
Tin	0.2–0.85	1.1–4.8
Lead	0.3–7.5	1.3–3.9
Iron	30–60	0.1–11.4
Nickel	0.7–2.0	0.3–1.6
Gold	0.0005	0.0029–0.112
Silver	0.0005	0.01–0.52

(Bizzo et al. 2014)

Research focuses on the Printed Circuit Boards

Contains up to 40 different metals

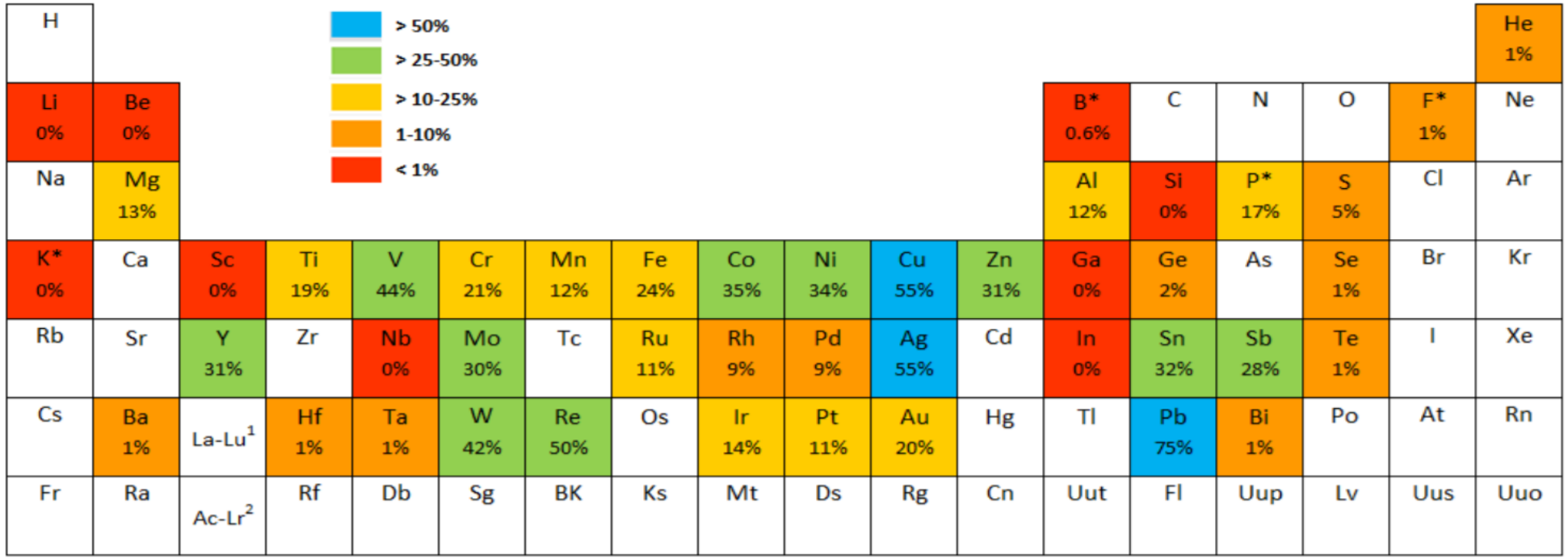
Higher metal content than in ores

Critical Raw Materials

Critical Raw Materials			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

(European Commission 2018)

End-of-life recycling input rate (EOL-RIR) [%]



H																	He 1%
Li 0%	Be 0%											B* 0.6%	C	N	O	F* 1%	Ne
Na	Mg 13%											Al 12%	Si 0%	P* 17%	S 5%	Cl	Ar
K* 0%	Ca	Sc 0%	Ti 19%	V 44%	Cr 21%	Mn 12%	Fe 24%	Co 35%	Ni 34%	Cu 55%	Zn 31%	Ga 0%	Ge 2%	As	Se 1%	Br	Kr
Rb	Sr	Y 31%	Zr	Nb 0%	Mo 30%	Tc	Ru 11%	Rh 9%	Pd 9%	Ag 55%	Cd	In 0%	Sn 32%	Sb 28%	Te 1%	I	Xe
Cs	Ba 1%	La-Lu[1]	Hf 1%	Ta 1%	W 42%	Re 50%	Os	Ir 14%	Pt 11%	Au 20%	Hg	Tl	Pb 75%	Bi 1%	Po	At	Rn
Fr	Ra	Ac-Lr[2]	Rf	Db	Sg	BK	Ks	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

[1]Group of Lanthanide	La 1%	Ce 1%	Pr 10%	Nd 1%	Pm	Sm 1%	Eu 38%	Gd 1%	Tb 22%	Dy 0%	Ho 1%	Er 0%	Tm 1%	Yb 1%	Lu 1%
[2]Group of Actinide	Ac	Th	Pa	U	Np	Am	Cm	Bk	Cf	Es	Fm	Md	No	No	Lr

Aggregates	Bentonite	Coaking Coal	Diatomite	Feldspar	Gypsum	Kaolin Clay	Limestone	Magnesite	Natural Cork	Natural Graphite	Natural Rubber	Natural Teak Wood	Perlite	Sapele wood	Silica Sand	Talc
7%	50%	0%	0%	10%	1%	0%	58%	2%	8%	3%	1%	0%	42%	15%	0%	5%

* F = Fluorspar; P = Phosphate rock; K = Potash, Si = Silicon metal, B=Borates.

(European Commission 2018)

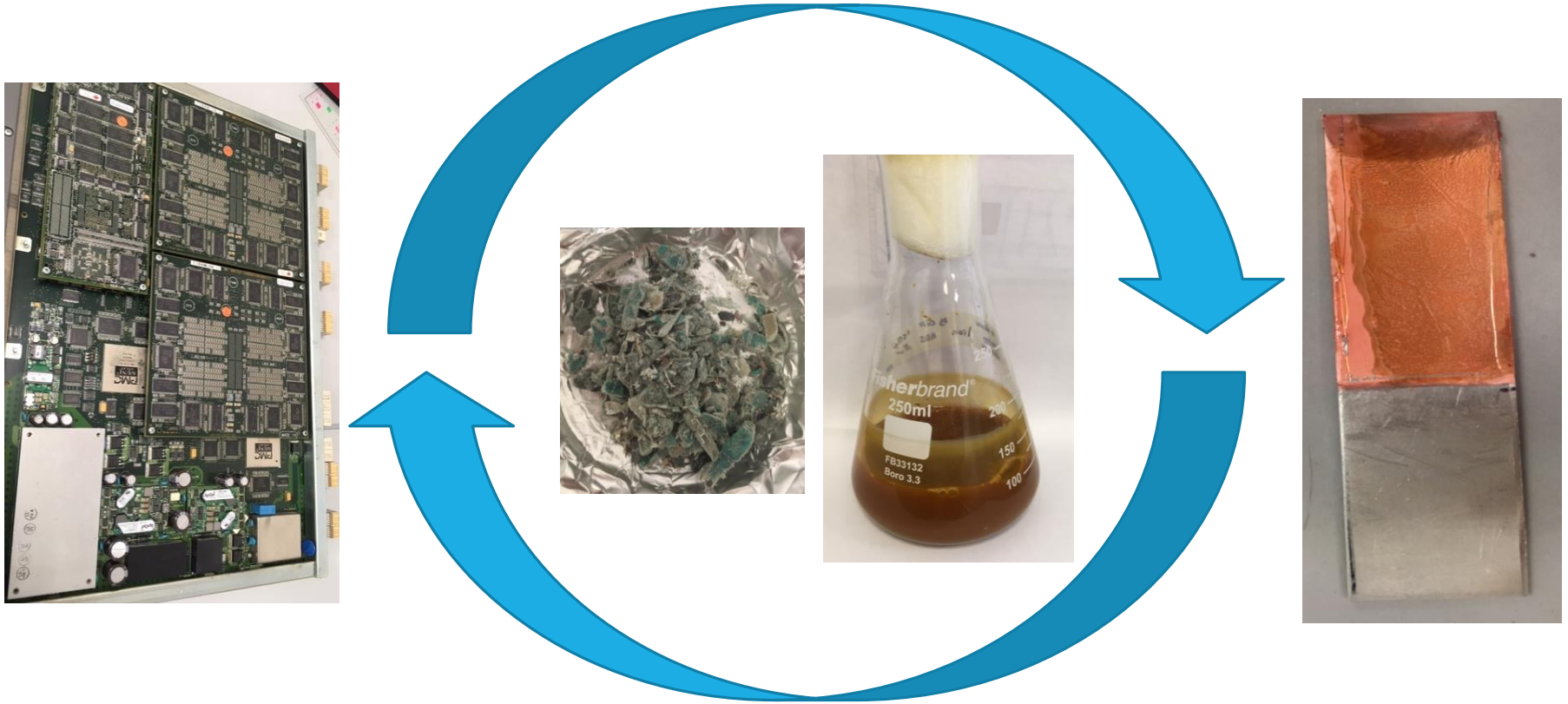
Circular Economy

UK is striving toward a Circular Economy

Many natural resources are not located in the UK

Estimated around £45,000 of Gold in 1 tonne of E-waste

Research at Coventry University



Current Recycling Methods

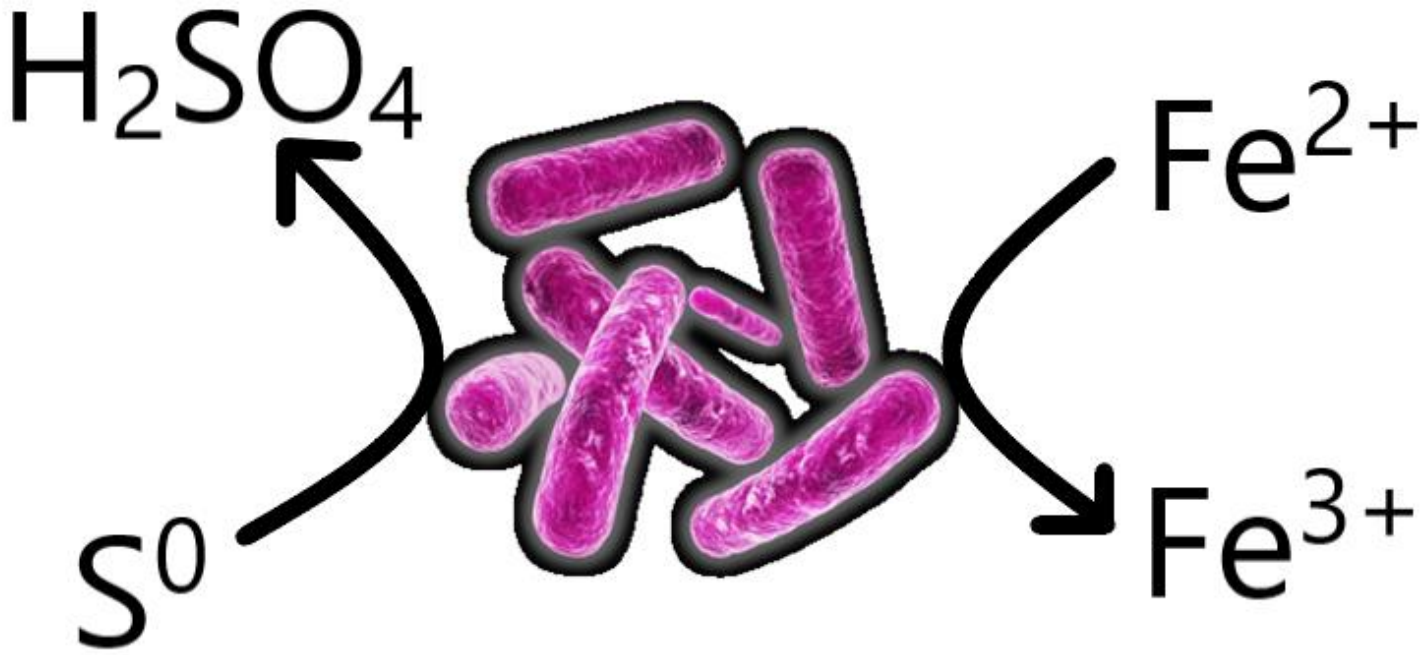
Pyrometallurgy

Methods that use high temperatures such as Pyrolysis or Smelting

Hydrometallurgy

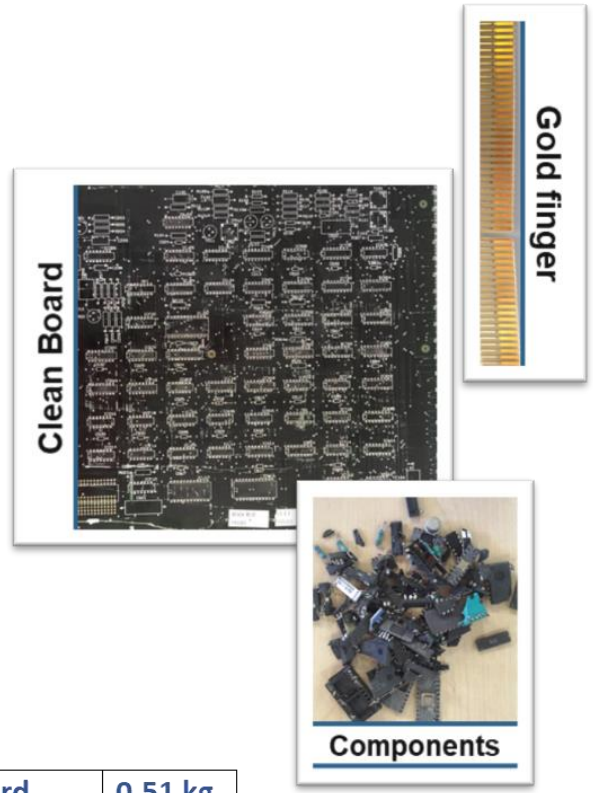
Methods that utilise chemical lixiviants – Cyanide, Acids

Bioleaching



Manual and Mechanical Separation

- Magnetic separation
- Eddy current separation
- Shaking tables
- Size reduction



System X Board	0.51 kg
Clean Board	0.34 kg
Board Components	0.16 kg
Gold Finger	0.01 kg

Bioleaching for Base Metal Recovery

- Shredding clean boards
- Growing bacteria
- Addition of shredded PCBs (two-step bioleaching)
- Base metal dissolution in medium
- Filtration

Metal extraction from solution

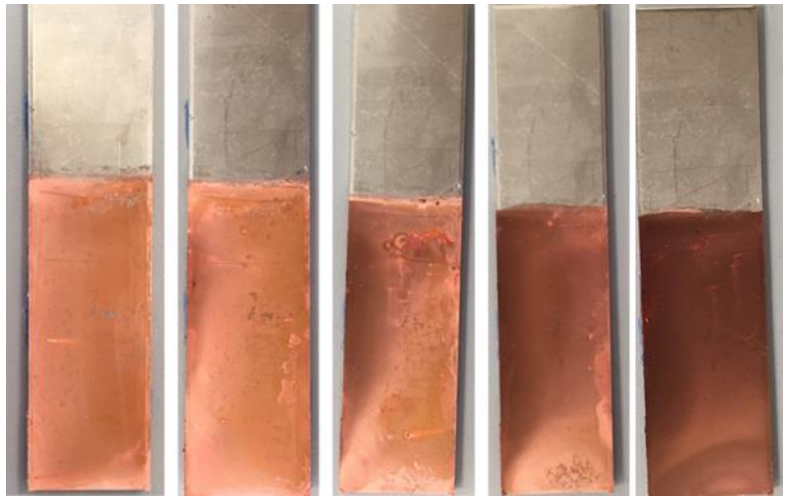
Electrowinning

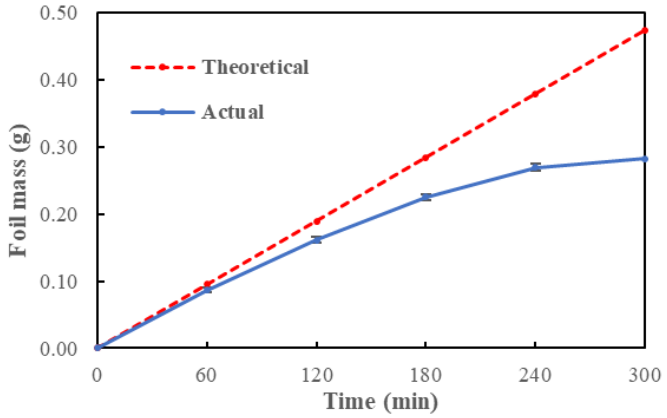
Challenge of having very heterogeneous solution

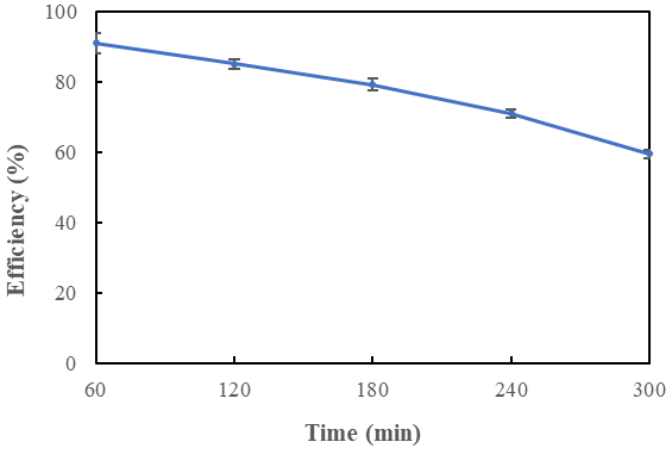
Metal	Na	Mg	Al	Mn	Zn	Fe	Ni	Cu
Concentration (mg/l)	17	56	180	6	19	400	17	2230
Standard potential (V)	-2.71	-2.37	-1.6	-1.19	-0.76	-0.45	-0.26	+0.34

Optimisation of Electrowinning Process

Testing mimic solutions, to find optimum conditions for current density

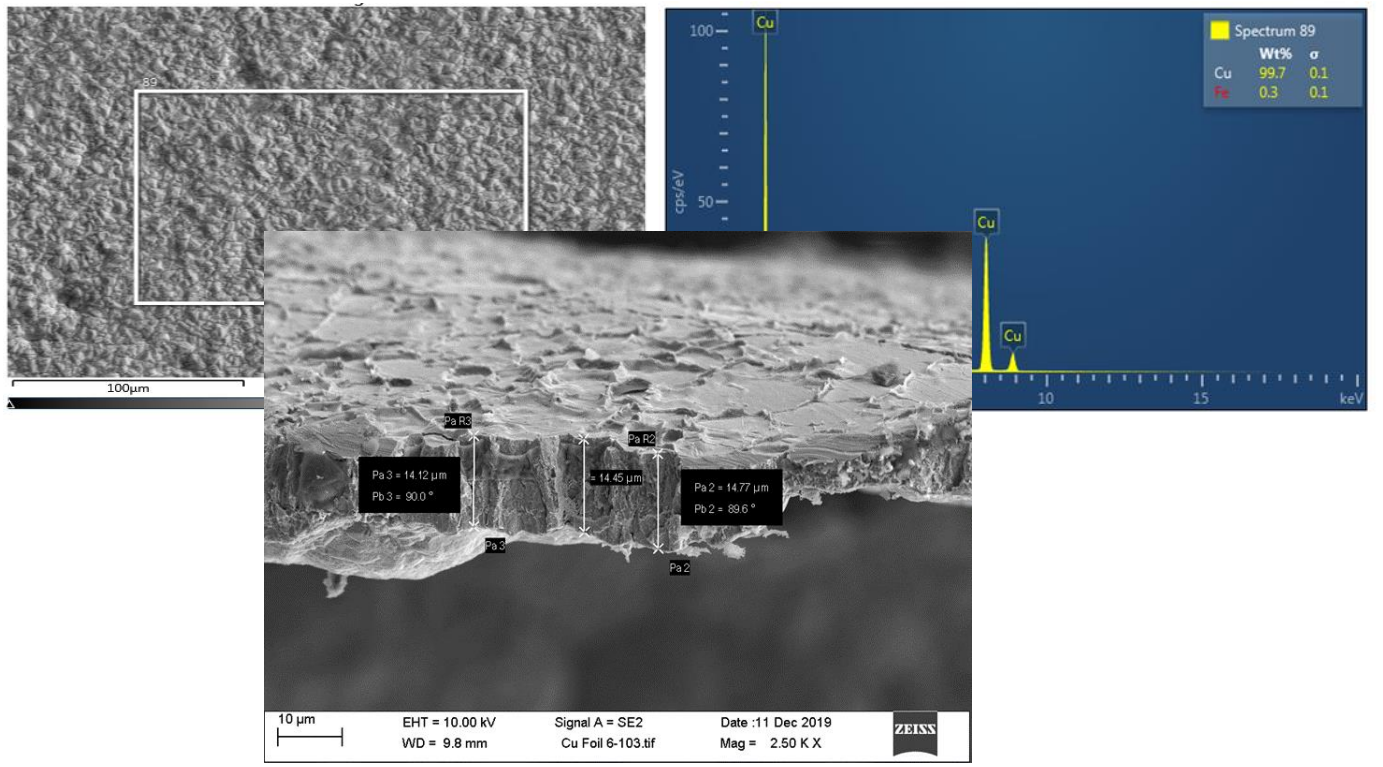




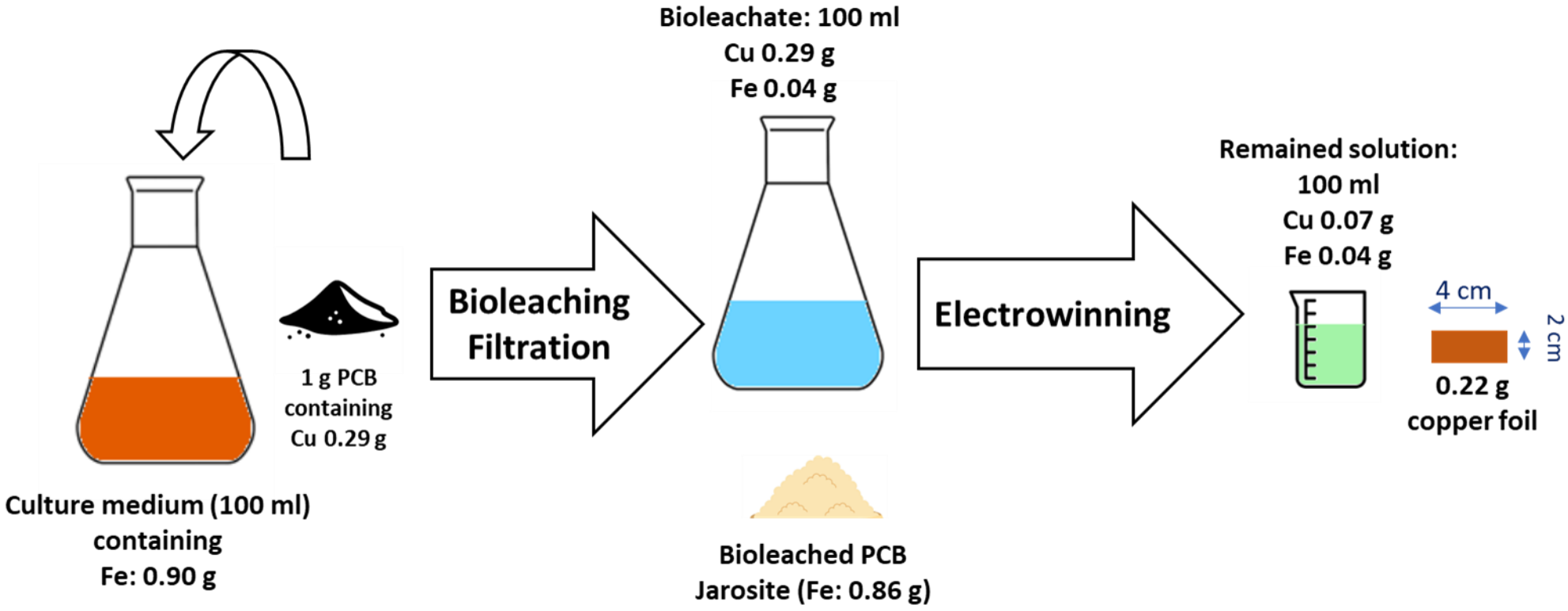


Characterisation of Product

Measuring purity and thickness with SEM, EDX



Flow Diagram



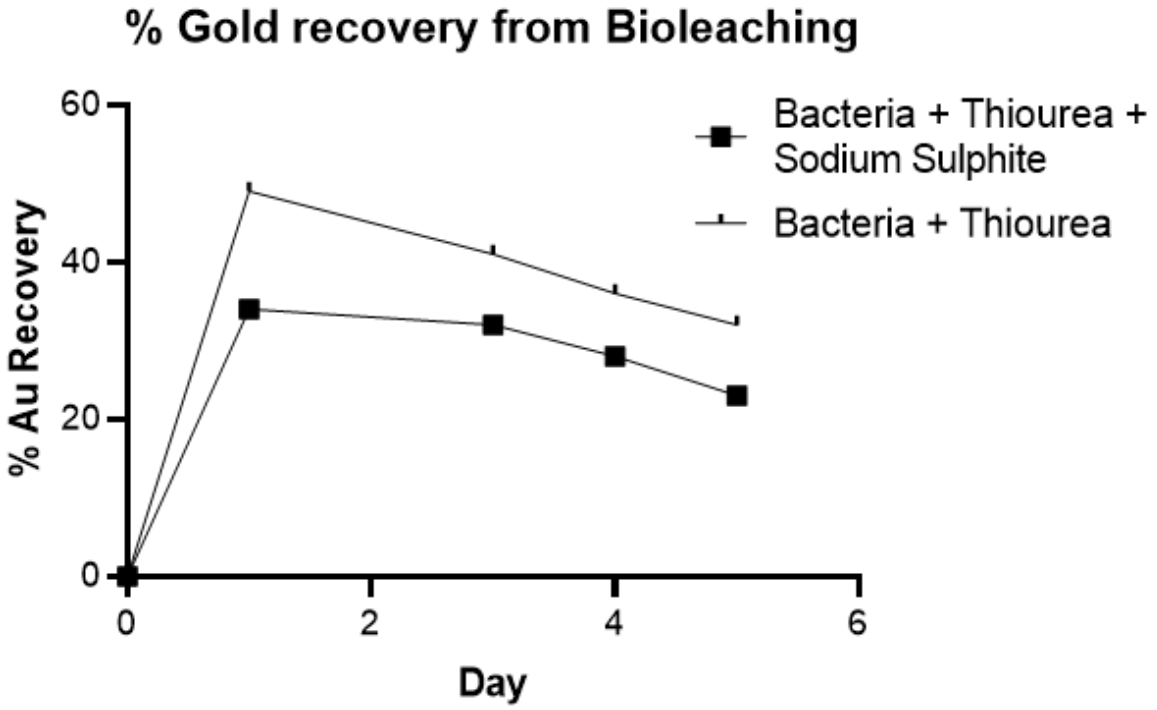
Gold Bioleaching using Thiourea

Typically gold bioleaching uses

biogenic Cyanide

Cyanide is extremely harmful and toxic

Thiourea is a less harmful alternative



$$Au + 2CS(NH_2)_2 + Fe^{3+} \rightarrow Au(CS(NH_2)_2)_2 + Fe^{2+}$$

Indium Bioleaching from screens

Indium is a Critical Raw Material

China have over 70% of natural resources – estimated to run out in the next 100 years

0% of Indium is currently recycled

Utilises Acidolysis bioleaching mechanism

Future Research

- ✓Increase pulp density (adaptation)
- ✓Reuse of materials
- ✓Precious metal recovery
- ✓Genetic modification of bacteria
- ✓Large scale application

Group Links

https://www.edie.net/news/7/E-sustainability-Alliance--Defra-launches-new-coalition-championing-green-IT/

https://www.coventry.ac.uk/research/areas-of-research/sports-exercise-and-life-sciences/bioleaching-group/

https://www.coventry.ac.uk/research/areas-of-research/sports-exercise-and-life-sciences/bioleaching-group/our-team/