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Bioleaching of electronic waste

Knowledge Transfer Partnership

Coventry University

Innovate UK

n2s
network 2 supplies ltd

Metal recovery from E-waste

WEEE production 44.7 Mt annually in the world and 2 Mt in the UK:

- Urban mining and secondary resources
- Economic and environmental incentives

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, Characterization of Printed Circuit Boards for Metal and Energy Recovery after Milling and Mechanical Separation, Materials, 7: 4555-66.

Part of ICT supply chain

"The European Union directive 2012/19/EU is based on the Extended Producers Responsibility, which considers the manufacturers as responsible for e-waste management"

Methods for metal recovery

Conventional methods

- Pyrometallurgy
- Hydrometallurgy

Sustainable method

Bioleaching

Bioleaching

Production of acids and ligands with microorganism:

- ✓ Acidolysis

  Organic and inorganic acid production

- ✓ Complexolysis

  Production of chelating agent

- ✓ Redoxolysis

  Enhancement of available ions in the solution

Biocyanidation

- ✓ Gold recovery from mineral ores by cyanide is common practice
- ✓ Cyanogenic bacteria produce cyanide in a reasonable amount
- ✓ Intrinsic ability of microorganisms to degrade cyanide

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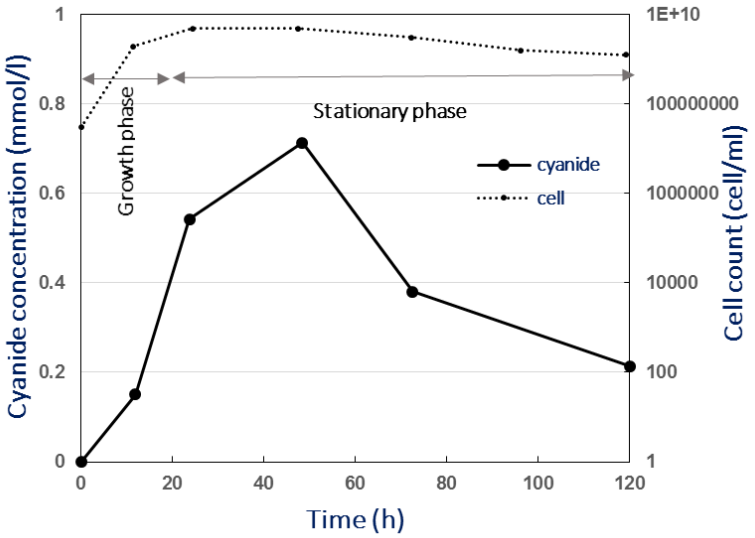
Kita, Y., et al. (2009) Enhancement of Au Dissolution by Microorganisms Using an Accelerating Cathode Reaction. Metall. Mater. Trans. B 40, 39–44.



Metal-cyanide complex formation

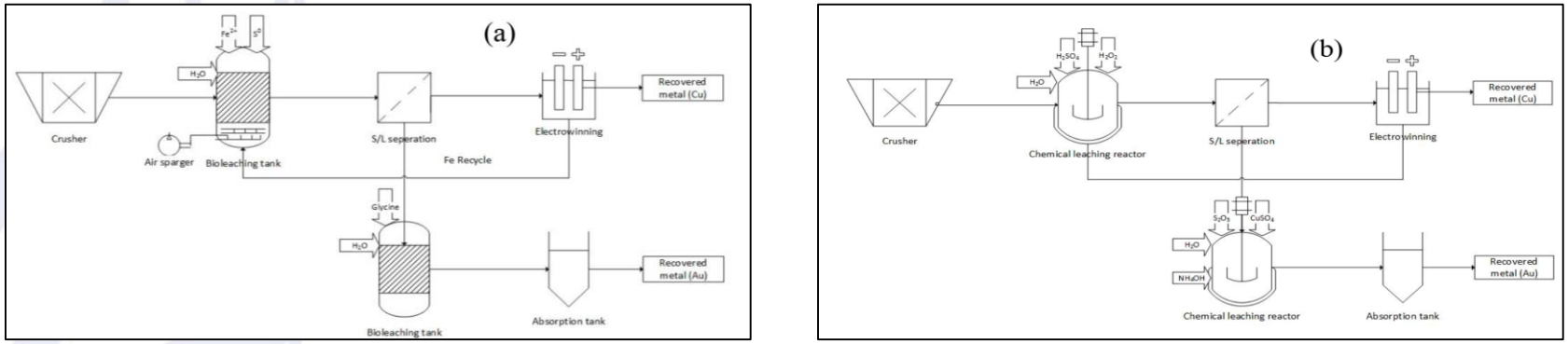
Elsner's equation

Formation of dicyanoaurate anions:

$$4\ Au(s) + 8\ NaCN(aq) + O_2(g) + 2H_2O(l) \rightarrow 4\ Na[Au(CN)_2](aq) + 4\ NaOH(aq)$$

Biocyanidation vs. Chemical cyanidation

Techno-economic assessment of chemical biological and combined process



Isildar A. 2018. Metal Recovery from Electronic Waste: Biological Versus Chemical Leaching for Recovery of Copper and Gold. CRC Press.

Technology	Operational cost	Investment cost	Total cost	Net revenue	Return of interest	Climate change contribution
	(euro/kg PCB)				year	Kg CO_2/Kg PCB
Biological	0.159	0.457	0.616	4.41	5.1	8.26
Chemical	0.224	0.446	0.670	8.97	2.4	14.6
Hybrid	0.232	0.777	1.008	8.25	4.3	11.6

Improving recovery by biocyanidation

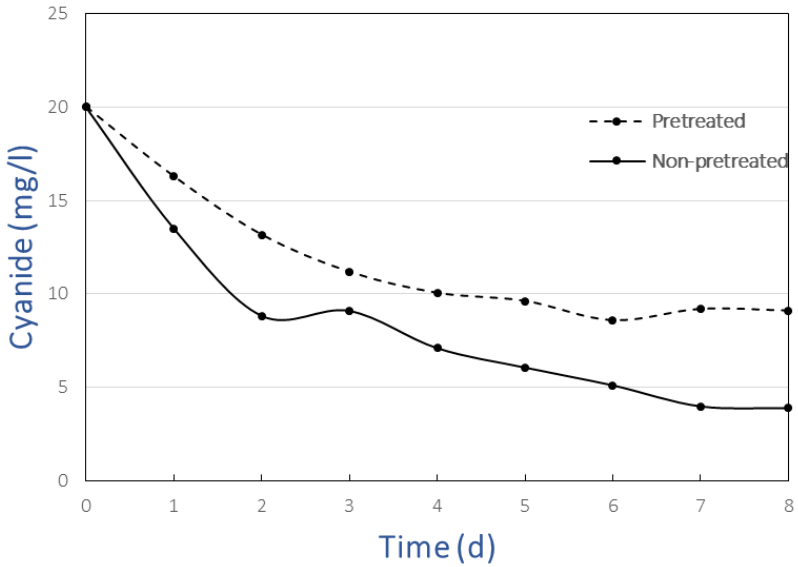
- Non-metal content removal
- Necessity of base metal recovery in first steps
- Effect of operation of parameters
- Effect of process configuration

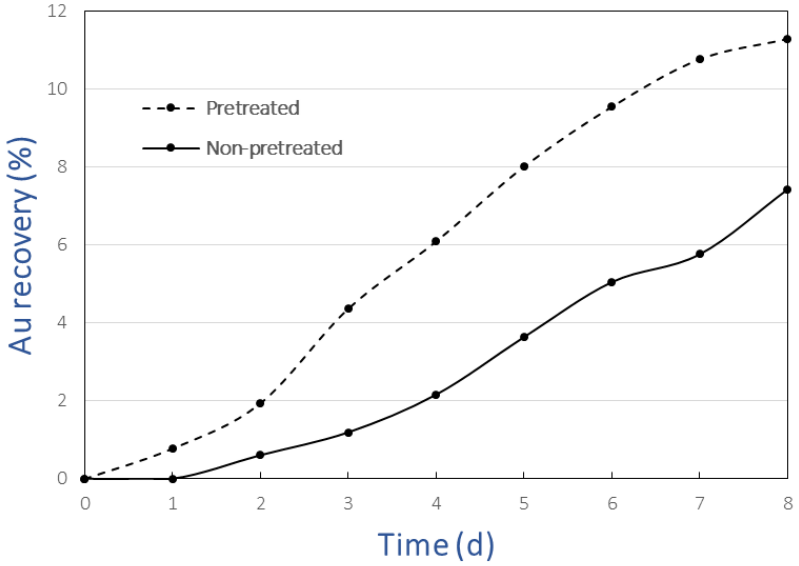
Non-metal content removal

- Shaking table
- Electrostatic separation
- Magnetic separation

Base metal recovery

Base metals always win the competition versus noble metals





Natarajan, G., Ting, Y.-P., (2014) Pre-treatment of e-waste and mutation of alkali-tolerant cyanogenic bacteria promote gold biorecovery. Bioresour. Technol. 152, 80–85.

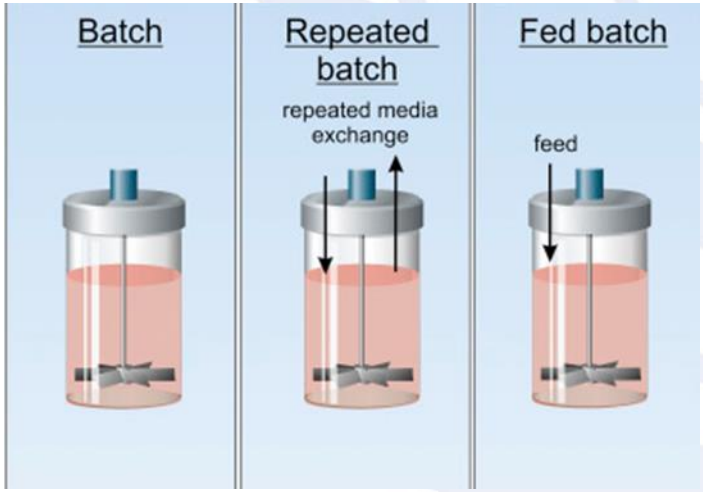
Effect of operational parameters

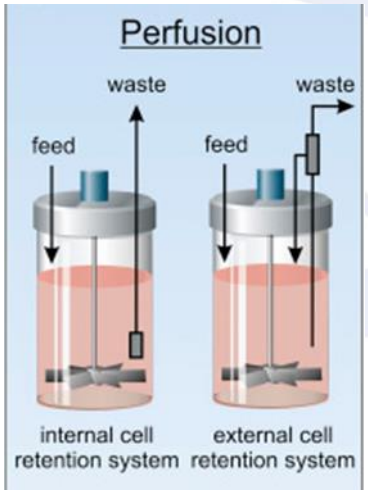
- Necessity of process optimisation
  - Glycine concentration
  - pH (chemical and biological effect)
  - Pulp density (tolerance to toxic)
  - Dissolved oxygen
  - Particle size

Process configuration

- One step
- Two step
- Spent medium

- Reactor configuration
  - ✓ Batch
  - ✓ Fed-batch
  - ✓ Continuous





Metal extraction from the solution

- Merrill-Crowe process
- Carbon active
- Ion exchange
- Electrowinning


Thanks for
your attention