TESTING SEPARATION TECHNIQUES TO RECOVER VALUE FROM CIRCUIT BOARDS

Outcomes of a CRM Recovery Trial in Scotland, UK

The Critical Raw Material (CRM) Closed Loop Recovery Project aims to increase the recovery of target CRMs by 5% by 2020 and by 20% by 2030. To achieve this, the project has invested in trials exploring novel ways to boost the collection and recovery of CRMs from household waste electrical and electronic equipment (WEEE).

One such recovery trial was led by Re-Tek (an ICT Asset Management organisation based in East Kilbride), Enscape Consulting (a specialist consultancy based in Aberdeenshire and Stirling) and the University of the West of Scotland (UWS).

Trial Context

Current treatment routes for printed circuit boards (PCBs) recover only common and high volume valuable metals. Other rare earth elements are lost as they are present in low quantities and recovery is not currently economically viable.

The objective of this recovery trial was to develop 'proof of concept' benchtop experiments that used biological and chemical separation techniques to extract gold, silver and cobalt from collected PCBs.

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Linking WEEE Collection and CRM Recovery

The recovery activities directly followed the successful completion of collection trials, including a school collection trial[i], which enabled both business to consumer and business to business WEEE to be processed at the Re-Tek facility using the organisation's standard procedures that have been developed and tested over a number of years.

As part of the collection trial, the first consideration was whether the WEEE had any re-use and / or resale potential. The items that didn't, and were therefore only suitable for reprocessing, were stored separately, with the target PCBs extracted and stored for the research to be carried out in the Phase 2 recovery trial. This type of WEEE can be categorised as equipment that was too old and / or uneconomical to repair, or of low specification.

Methodology

The IT products unsuitable for re-use, were transported to the University of the West of Scotland, to be processed for precious metal and critical raw material recovery.

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Biological separation

Three types of microbe were utilised (acidophiles, fungus and cyanogenic) to determine whether they would selectively extract gold, silver and cobalt from ground PCBs.

Chemical separation

Three chemical separation techniques were explored to extract gold, silver and cobalt:

i) acid dissolution;

ii) sulfide precipitation.

iii) particle size distribution.

Electrochemical Cell (EC Cell)

14 proprietary EC Cells were manufactured for the recovery of gold, silver and cobalt from reference solutions.

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Trial Outcomes (summary)

Experimental Method	PCB or Reference Sample	Starting Concentration (ppm)				% of Target Metals in Samples Recovered			
		Au	Ag	Co	Cu	Au	Ag	Co	Cu
2-stage Bioleach[b]	PCB	-	-	-	-	1 – 22%	-	6 -13%	0.6 - 8%
Hydroquinone[a]	Gold standard	200	-	-	-	314%	-	-	-
	Gold standard	1,000	-	-	-	166%	-	-	-
EC Cells[a]	Ref solution	200	200	200	-	99.6%	94.7%	98%	-
Precipitation	Ref sample	1	1	1	1	95.9%	96.3%	50.1%	53.6%

Table notes 1: a. This used a reference solution (a reference solution is a solution made up in a laboratory to a known concentration of the analyte of interest); b. Indicative results because of elevated abiotic control results. A range of results were achieved for different starting concentrations. This table summarises the highest recovery results achieved for 200ppm concentrations.

Table notes 2: Au=Gold; Ag=Silver; Co=Cobalt; Cu=Copper; ppm=parts per million.

To summarise, the initial EC Cells results were promising, with gold, silver and cobalt recovery rates at 99.6%, 94.7% and 98% respectively.

Trial Feedback

The results from the recovery trials provided both technical and general learnings as follows.

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Technical feedback

- *Chemical separation*. The initial sulfide precipitation experiment was slow because only one precipitation reaction at a time could be run. There is an opportunity that future research could allow multiple samples to be precipitated simultaneously.

- *EC Cell.* Carbon production was slower than anticipated because the current production approach resulted in poor growth of some batches affecting the length of time that it took to produce sufficient carbon for each cell. This would need to be a factor in the assessment of the commercial and economic viability of the method.

- *Biological separation*. The cultivation of the microbial strains is inherently variable. It is recommended that all experiments are replicated a suitable number of times (three or more) to account for the biological variability and the non-uniform nature of the PCBs, with multiple abiotic controls to generate statistically robust data.

General learnings

- *Economics*. Based on the recovery systems trialled, it would appear to be both economically and environmentally advisable to ensure that WEEE collection schemes enable as many items as possible to be processed for re-use markets prior to recovery / recycling.

- *Limitations.* Despite extensive consultations with a range of industrial and research organisations, the trial team could not source a shredder suitable for direct processing to grind PCBs into a powder (requiring intensive laboratory preparation). Because the trials were laboratory proof of concept, homogeneous, finely powdered samples were needed to minimise replicate variation.

- *Future activity*:

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1. Some of the proof of concept laboratory experiments demonstrated high recovery rates of the target elements. However, more laboratory work is needed before these separation techniques would be commercially viable.

2. The trial has highlighted that a recovery methodology which uses a range of mechanical and chemical stages (as outlined above) may be the most effective at recovering CRMs from PCBs.

3. This trial was a proof of concept activity. Some results appear promising, but further funding is needed to refine the processes that were initially trialled within this project.

Benefits

- This CRM Recovery Project trial has tested and demonstrated a number of promising repeatable, lab-scale (but scalable) processes for the recovery of CRMs from WEEE items.

- The trial has also successfully demonstrated the important link between WEEE collection and CRM recovery, which can serve to increase the latter.

- The learnings and outcomes of this trial have provided valuable input into the EU-wide policy and infrastructure recommendations that will be published shortly, and which could be applied in a commercial setting to increase the recovery of CRM-rich components from data-bearing devices.

[i] Schools and parents join forces

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