WEEE collection and CRM recovery trials: piloting a holistic approach for Scotland

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Abstract

Re-Tek UK and its partners, Enscape Consulting and the University of West of Scotland commenced trials for the collection and recovery of critical raw materials from waste electrical and electronic (WEEE) products in July 2016. Sponsored by WRAP CRM (Life funded) the trials are aimed at boosting the recovery of critical raw materials (CRMs) from household waste electrical and electronic products (WEEE) and Information Communications Technology (ICT) in particular, after functioning equipment is separated out for re-use. The new collection models provide residents with the opportunity to drop-off unwanted electrical and electronic appliances at a time and place that suits them, through a collaborative approach which encourages local authorities, educational establishments, businesses, and Social Enterprises etc to act as hub sites. Hubs are designed to minimize product damage and encourage drop-off, rather than hoarding. Extraction methods developed after the collection phase of the trial will advance the opportunity to recover Cobalt, Gold and Silver from ICT products, with the potential to inform how a more sustainable supply chain could be developed in Scotland. These are based on bioleaching and electrochemical recovery using novel carbon based electrode systems, with an assessment of pilot performance and scale up challenges. We report on progress to contribute to an EU Life project covering pilot studies across Europe to provide definitive data on practical solutions to WEEE and CRM recovery.

Keywords: critical raw materials, bioleaching, electrochemical recovery, electronic equipment collection, hub sites, cobalt, silver, gold

1. Introduction

Waste Electrical and Electronic Equipment (WEEE) is currently considered to be one of the fastest-growing waste streams in Europe. Currently, the world generates around 40 million tonnes of e- waste every year (Balde *et al*, 2015). E-waste is of serious concern due to the loss of valuable Critical Raw Materials (CRMs) which are also often hazardous materials, with the potential for significant impacts, which must be mitigated against, if disposed of to landfill or incinerated. The environmental impacts of disposal practices across the world are often most severe in developing countries, where vulnerable communities are often most at risk. Demand for raw material, in particular for precious metals or CRMs, is growing due to their value to a range of different manufacturing sectors and on-going concerns regarding the security of their supply. The Critical Raw Materials Closed Loop Recovery project is delivering a series of collection and recovery trials that consider the impact of collection on reuse and recovery potential on WEEE and materials it contains. The information and evidence gathered through the trials will support the development of a European wide infrastructure plan and policy recommendations (EU Commission 2008) to support the increased recovery of critical and valuable materials from WEEE. By evidencing the potential of collection and recovery techniques this project has the ability to impact the industry by increasing the availability of critical raw materials (CRMs) for use in new products. This study forms one of a number of studies being developed through EU LIFE funded Critical Raw Material Closed Loop Recovery project, coordinated by WRAP (UK) (REF). The outcomes of the project provide information and data to inform: The type and quantity of equipment that can be collected from a number of different collection/logistics models. From this, equipment suitable for re-use has been sold into markets, with the residual equipment, suitable for reprocessing, identified and Printed Circuit Boards (PCBs) selected for the innovative reprocessing techniques forming part of Phase 2.

• How ICT WEEE that cannot be reused can be responsibly recycled using a method that maximizes CRM recovery cost effectively and safely.

• How current and evolving policy and reuse/recycling infrastructure status is able to facilitate the delivery of the vision e.g. through regulations, good practice, systems, economics etc.

2. Methods

The project is split into two phases, as summarized below:

• Phase 1: Equipment collection, using the different collection/logistics models

• Phase 2: Selected PCBs prepared and processed using innovative biological and electro-chemical methods - for the extraction of Critical Raw Materials (CRMs). The collection models trialed by the Re-Tek-led team were developed to provide consumers with the opportunity to drop-off unwanted electrical and electronic appliances at a time and place that suited them, to reduce hoarding of potentially valuable resources. The approach was a collaborative one aimed at incentivizing local authorities, educational establishments, businesses, and social enterprises etc to act as hub sites. These hubs were also designed to minimize product damage and encourage drop-off. The type of equipment being sought was functional ICT as listed below:

Table 1: WEEE component collection categories

Laptops	Miscellaneous Audio/Video Devices
Desktop/Inkjet Printers	Personal computers
Compact Digital Cameras	Tablets
Computer Components	Flat Screen Monitors
Networking Items	Flat screen Televisions
Digital Set Top Boxes	Mobile Phones
Gaming Devices	New Printer Cartridges

The Phase 1 collections models involved establishing the following:

• Re-use containers at Household Waste Recycling Centers (HWRCs)

• Employee amnesty collections (B2B)

• Schools as collection hubs

• University Halls of Residences as collection hubs (Halls)

• Social economy organizations, as collection partners.

Phase 2 involves the set- up of novel laboratory based investigations for the recovery of gold, silver and cobalt from WEEE in an electrochemical flow system consisting of a series of electrochemical cells. The method of metal recovery will be electrodeposition in which metal ions in the treatment solution (obtained by the dissolution of shredded WEEE in aqueous acidic solution) will be recovered at the cathode where the positive metal ions in the solution migrate and are deposited as high purity metal.

The potential of microbial biomass to solubilize/mobilize specific metals from WEEE as a pre-treatment or hybrid recovery methodology will be also examined by Bioleaching. This will include solid/particulate WEEE pre-treatment in agitated mini-reactors (flasks) under specific conditions (dependent on microbial biomass used) and performance analysis of the process (by atomic spectroscopy ICP-AES/MS), including the analysis of filtered liquid culture media after microbial incubation with solid WEEE samples. This paper looks at the result of Phase 1, and impact on plans for Phase 2.

3. Results and Discussion

Summary data for the material collected from the various collection models is shown in Figure 1. This identifies numbers of items collected and includes an indication of any subsequent reuse post collection as well as an age distribution of items recovered. Total weight of items from each collection method is also identified. In summary:

a) The outcome of Phase 1 collection model trials indicates just over 90% of the pre-project estimates of equipment that would be collected, were actually collected (the former based on industry benchmarking).

b) The levels of re-use achieved from all of the collection models trialed are significantly less than is often found to be the case from mainstream, ongoing business to business contracts (which typically exceed 80%). Re-use levels ranged from 27% for equipment donated through HWRCs to 30% and 36% for equipment donated through schools and Social Enterprises, respectively. There are considered to be many reasons for such low levels, one of which is that equipment donated appears to be older. An average of 8.6% of equipment (across all collection models) was between 0 and 3 years old, with 59.7% in the range of 3 to 6 years.

c) The age range of equipment collected as a whole did not vary significantly for the different collection models. However, when different categories of equipment were considered there were significant difference in age ranges and levels of re-use. 95.7% of all the equipment collected in Phase 1 fell under two categories: ICT (71%) and TVs and monitors (24.7%). HWRCs resulted in 11.5% re-use, with School and B2B collections more than double this (25.4% and 23.4% respectively).

d) HWRCs provided a significantly lower percentage of ICT than the other models – 64% compared to between 73% and 89%. A significant contribution to the HWRC re-use rate, overall, was related to flat screen TVs and monitors. Flat screen TVs and monitors may represent a potential opportunity for HWRCs due to the relatively higher reuse rates and revenue generated. Increasing numbers of HWRCs are already providing separate containers for screens (for recycling). The approach to collecting ICT separately needs further consideration due to what appears to be a reluctance amongst consumers to donate high value data-bearing devices to HWRCs.

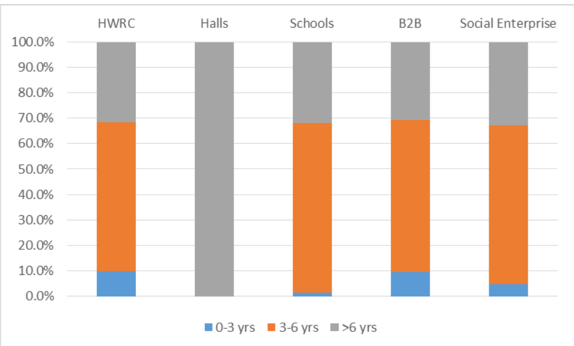

Figure 1 WEEE recovery data: items collected % by age rom each collection method

e) Significant differences in the types of Core ICT equipment collected were seen, for the different collection models e.g. 42.4% of HWRC and 38.3% of Social Enterprise WEEE were printers. This compares to between 3.4% and 11.5% for Schools and B2B collections.

f) Considering the Core ICT category alone (smartphones, mobile phones, tablets, PCs, laptops) there were significant differences in the profile of equipment depending on the collection model employed. 50% and 53% of the ICT collected through HWRCs and Social Enterprises respectively was Core ICT, while 73% of the ICT collected from Schools and B2Bs were ICT. HWRCs and the Social Enterprise collections included significantly higher levels of printers (>40%) which have very little, if any, re-use/resale potential.

g) The ability to generate viable re-use income streams from C2B collections is more challenging than for B2B, and will continue to be the case unless equipment hoarding is minimized, a situation which is likely to mean that enhanced versions of the collection models trialed are developed, and/or alternative approaches are taken forward in the future.

The collection of individual PCBs from equipment identified in phase 1 presents the input feed to phase 2. The preparation of material requires further processing, primarily in size reduction using mechanical shredding in a manner that is viable for bulk waste processing. Size reduction introduces greater surface area for bioleaching and digestion of the solid phase but the process also generates issues of dust production, fractionation of metal phases and inhomogeneous residues (Oguchi *et al*, 2012). Plastic and metal components perform variably under mechanical treatment and introduce high heterogeneity into shredded product (Ruan & Zum 2016). A systematic analysis of a number of commercial shredding facilities was undertaken and “best” option identified based on preliminary trials. Shredded test samples were assessed for particle size range. Further impact on phase 2 will be addressed through replicate digests for both total metal and bioleached. The scope of the study does not allow optimization or development of full protocol for preparation but highlights some confounding factors

4. Conclusions

a) The Phase 1 collection trials may indicate that consumers prefer to donate potentially data bearing equipment to schemes that are embedded within the community e.g. through schools and social enterprises, however a detailed investigation into consumer motivations, to donate/ hoard equipment would be useful to target future campaign materials and refine collection schemes to maximize newer, higher value equipment.

b) Consider maintaining support and working closely with local social enterprises and schools, which have a local dimension, and have a trusted relationship with the local community. With little in the way of infrastructure required to develop such relationships, the main risks to consider are the cost of staff time to support this. Such relationships may also provide benefits in terms of wider appeal to the community, and access to additional funding revenues which may enable cost-effective schemes to be delivered. In addition, associated with such initiatives would be the wider social benefits of providing work and volunteering opportunities to vulnerable members of the community, doing so within a circular economy context.

c) There would appear to be an opportunity to target flat screen TVs/monitors at HWRCs, since at this point in time they are not perceived to be data bearing equipment in the way that laptops, PCs, tablets and smartphones are. Many HWRCs already segregate screens, and targeting flat screen TVs and monitors for reuse may be a particularly viable collection opportunity. Targeting larger items such as flat screen TVs and monitors may also help to change the culture of hoarding due to the amount of space required to store these items in the home and encourage consumers to view the end of life of all devices differently.

d) The compliance scheme model, and how it supports Social Enterprises, is an area that could be considered further, in terms of how it evolves to support collaboration and greater income sharing among these potentially effective delivery partners in the future.

e) Discussions have indicated that it is important to gain a good understanding of the contractual status of local authorities and their compliance scheme partners, in terms of the type/quantities of WEEE being removed from HWRCs. Where the contractual circumstances mean that there are opportunities to divert WEEE from recycling, for re-use, there would be benefits in work being undertaken to quantify this and to feed it back so that the scale of the opportunities are understood.

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