URBAN MINING: A SUCCESSFUL EXPERIENCE OF THE EU-FP7 HYDROWEEE PROJECT

Extended abstract

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Background

The final disposal of electrical and electronic devices is an issue of current worldwide concern. Disposal and incineration can pose threats to the whole environment, from the atmospheric to the aquatic and terrestrial compartments. Indeed, gases produced during thermal treatments (e.g. dioxins, furans, polybrominated organic pollutants and polycyclic aromatic hydrocarbons) can be released into the environment if adequate flue gas cleaning systems are not implemented. Similarly metals can be released from waste electrical and electronic equipment (WEEE) disposed of in landfill sites by leaching processes. As man-made devices such as electrical and electronic equipment, accumulators and fluorescent lamps are rich in valuable metals (e.g. Au, Ag, Cu, Zn, Co, Y), WEEE recycling for the production of secondary materials needs to be encouraged (Ongondo et al., 2011)

In the current scenario, recycling policies are gaining more attention, and many countries have drawn up regulations for the management of WEEE, including European Union, the United Kingdom, China, Japan, South Korea, Taiwan, some states of the U.S.A. In particular, the European WEEE Directive (EC Directive, 2012) aims at WEEE recycling, to reduce the disposal of waste and “to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials”. WEEE represents a source of metals, which have been mined from ore minerals, where they are often present at low concentrations: indeed, these are included at higher concentrations as the pure metals or metallic alloys in electrical and electronic equipment. Considering this context, “urban mining” looks more attractive than the conventional one.

Objectives

The main objective of this manuscript is the presentation of a successful case study of urban mining dealing with two research projects funded within the European FP7 framework: HydroWEEE (2009-2012) and its follow up HydroWEEE-DEMO (2012-2016).

Outline of the work

This manuscript is addressed at presenting a successful example of urban mining, achieved within EU-FP7 funded projects. The first FP7-Research for SMEs project HydroWEEE (2009 – 2012) dealt with the recovery of rare and precious metals from WEEE including lamps and spent batteries. Innovative processes feasible for SMEs were developed and a mobile prototype was performed; this was fed with a metal rich fraction, residual of widely applied
physical processes for the recycling of metals from fluorescent lamps, cathode ray tubes (CRTs), spent Li-ion accumulators, printed circuit boards (PCBs), liquid crystal displays (LCD). Recovered metals were yttrium, zinc, cobalt, indium, copper, gold and silver. The objective of the follow-up FP7 - Environment project HydroWEEE Demo (2012 - 2016) is to build 2 industrial demonstration plants (1 stationary and 1 mobile) in order to test the performance and prove the viability of the processes from an integrated point of view (technical, economical, operational, social) including the assessment of its risks (including health) and benefits to the society and the environment.

![Fig. 1. Block diagram of the processes carried out in the HydroWEEE portable plant.](image)

**Results and discussion**

The processes addressed for the exploitation of WEEE residues (from fluorescent lamps, CRTs, Li-ion accumulators, PCBs and LCDs) were carried out in the portable plant from the HydroWEEE research project. Specific, essentially physical, pretreatments were carried out according to the kind of WEEE, which were aimed at the recovery of the main fractions (e.g. glass, plastics, metals) and at the production of the WEEE residues that are not treated by most small and medium enterprise (SME) recyclers at present. In particular, the pretreatments included crushing, sieving and Hg removal by distillation, for the fluorescent lamps (Fig. 1); disassembly and CRT recycling (e.g. with diamond cutting technology), for the CRTs (Fig. 1); sorting, dismantling and grinding for the Li-ion accumulators (Fig. 1); dismantling and panel shredding/milling for the LCDs (Fig. 1) and sorting, shredding, magnetic separation and aluminium separation, for the PCBs (Fig. 2). The initial characterization and preliminary tests of the WEEE residues were carried out on the powders produced from these pretreatments.

From the fluorescent tubes, these contained 5 % to 7 % Y, as oxides, with rare earth elements also present, such as Eu (although these were not targets of the purification within the HydroWEEE project). From the CRTs, there were 15 % to 20 % Y and 30 % to 35 % Zn, which were present as oxides and sulfur compounds. The ground electrode material produced after the Li-ion accumulator pretreatment contained 23 % to 25 % Li and 2 % to 3 % Co. As concerns LCDs, the ground panel had around 200 g/tonne In content. Finally, for the PCBs, there were 25 % to 28 % Cu, 400 g/tonne to 800 g/tonne Ag, and 1400 g/tonne to 1900 g/tonne Ag. These were thus the starting point for achieving the most suitable and effective treatments for metal extraction and recovery. The feed materials for the portable plant were thus the WEEE residues: fluorescent powders from fluorescent lamps and CRTs, ground electrode material from Li-ion accumulators, ground panel for LCDs and waste granulate material from PCBs. A leaching operation with sulfuric acid was a common unit operation for metal extraction (Y, Zn, Cu, Li, Co, In) from WEEE residues. For the Li-ion accumulator and PCB WEEE residues, hydrogen peroxide was also added under acidic conditions, as a reducing agent. In the case of PCBs, this was followed by a thiourea leaching step (for Au and Ag dissolution). The metal recovery from the leach liquor was carried out by selective precipitation operations, according to each of the specific metals to be recovered. The products were recovered here with extraction efficiencies of around 90 % for Y, Cu, Au, Ag, 93 % for Li, and >97 % for Co and In, with respective purities of 95 %, 99.5 %, 80 % (Au+Ag), 18 % and 43 %.

These relatively low purities are not suitable for direct commercialization (where at least 99 % would be needed), but these products are marketable to companies that use them as feed for a final purification. A final step of wastewater treatment was also considered, based on the use of lime for precipitation and neutralization processes. Figs. 1 and 2 show the block diagram of the processes. All of the details concerning the processes developed can be found elsewhere (De Michilis et al., 2011; Granata et al., 2012; Innocenzi et al., 2013; Kamberovic et al., 2011; Rocchetti et al., 2013). Figs. 3, 4 show images of the mobile prototype.

A life cycle assessment (LCA) was applied to the hydrometallurgical treatments carried out using the new portable prototype plant. The category of global warming potential was the most critical one considering the
specifications for southern European territories, with 13.3 kg CO₂/kg recovered metal from the powders/residues from fluorescent lamps, 19.2 kg CO₂/kg from CRTs, 27.0 kg CO₂/kg from Li-ion accumulators and 25.9 kg CO₂/kg from PCBs (Table 1). In general, these processes appear beneficial for the environment in terms of CO₂ emissions, especially for fluorescent lamps and CRTs. Further details can be found elsewhere (Rocchetti et al., 2013).

Table 1. Carbon dioxide emissions from the treatment of selected fractions of the WEEE residues

<table>
<thead>
<tr>
<th>HydroWEEE process</th>
<th>Primary process</th>
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<tbody>
<tr>
<td>Fluorescent powder from lamps</td>
<td>0.9</td>
</tr>
<tr>
<td>Fluorescent powder from CRTs</td>
<td>2.0</td>
</tr>
<tr>
<td>Ground electrodi material (Li-ion accumulators)</td>
<td>5.4</td>
</tr>
<tr>
<td>PCB granulate</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Concluding remarks

Waste from Electrical and Electronic Equipment (WEEE) is the fastest growing waste stream in Europe, that contains a high amount of valuable metals. In 2010 the Raw Materials Initiative of the European Commission (2010) defined 14 critical raw materials, most of rare metals which are used for electronic devices belong to this category. Hence innovative processes feasible for SMEs were developed and a mobile prototype was realized within the previous FP7-Research for SMEs project HydroWEEE (2009 – 2012). The follow up HydroWEEE-DEMO has been running for less than one year: processes are being improved, also addressing additional metals leading to the “critical raw material” list.
Two industrial scale, real-life demonstration plants (one stationary and one mobile) are in the construction phase and will be delivered soon, in order to test the performance and prove the viability of the processes from an integrated point of view (technical, economical, operational, social) including the assessment of its risks (including health) and benefits to the society and the environment as well as remove the barriers for a wide market uptake later on.

**Keywords:** electronic waste, hydrometallurgy, recycling, urban mining

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