Physical beneficiation approach of Graphite, Lithium and other metals from Electrical and Electronic Equipment Waste (WEEE) by Mineral processing techniques

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The global availability of raw materials is increasingly under pressure due to growing demand and the increasing likelihood of supply bottlenecks. Global resource security is a growing concern, and access to critical raw materials (CRM) has become a priority issue for governments around the world (European Commission, 2018; Černý et al 2021). In addition, due to the growing demand for electronic devices caused a global increase in Waste Electrical and Electronic Equipment (WEEE), amounting to 53.6 Mt in 2019 (Shittu et al, 2021). Therefore, overgeneration of WEEE has become an urgent problem worldwide. More importantly, WEEE contains a large number of components that can have harmful effects on the environment and humans, and its indiscriminate handling and informal recycling can make WEEE a global public and environmental health problem (Zhao et al, 2023). WEEE is an important secondary source of valuable and critical metals (Table 1). Generally, Electrical and Electronic Equipment (EEE) contains many critical metals including light and heavy rare earth elements (LREE, HREE), cobalt (Co), antimony (Sb), tungsten (W), etc., and platinum group metals (PGM), and near-critical elements such as tin (Sn), chromium (Cr), lithium (Li), and silver (Ag). They are essential components of EEE and have increasing importance in the transition to a green, low-carbon economy (Işıldar et al, 2019). In addition, the European Union estimated that in 2030 the demand for metals and rare earth elements (REE) would be 3 times the actual one. So, it is thus clear the importance of the issues related to their possible recovery from end-of-life (EOL) products (Palmieri et al, 2014).

Table 1. Example of the critical metal content (>1 ppm) of WEEE components (Işıldar et al, 2019).

WEEE Component	Metals	Concentration (ppm)
Main boards		
Printed circuit boards		
	Au, Pd, Ge, Ga	1 - 100
	Fe, Al, Ag, Ni	100 - 10000
	Zn, Cu	>10000
Batteries		
Li-Ion batteries	**Co, Li**	1-100
NiMH batteries	**Co, La,** Ni	100-10000
Memory drives		
HDD magnets	**Nd, Pr, Dy**	>10000
Solid state drives (SDD)	Cu, Ag, **Au**, Pd	1 - 100
Displays		
Liquid crystal displays (LCD)	**Y**, **In**, Sr	1-100
Light-emitting diodes (LED)	**Au, Ag,** In, **Sn**	1-100

In this work, the focus would be on Lithium-Ion batteries (LIBs) and Printed circuit boards (PCBs) since not only do they contain precious metals but also, but they are fastest-growing e-waste streams. First of all, for the determination of the chemical composition of the inorganic-based solid samples X-ray fluorescence Spectrometry (XRF), for elemental analysis, X-ray diffraction analysis (XRD), for mineralogical characterization Scanning Electron Microscopy (SEM-EDS) for morphological and semi-quantitative characterization was done, after sample preparation (Figure 1). The results of this analysis will present information about the content of particles, their structure, and liberation degree which is significant in this project to establish the separation processes for the key materials.

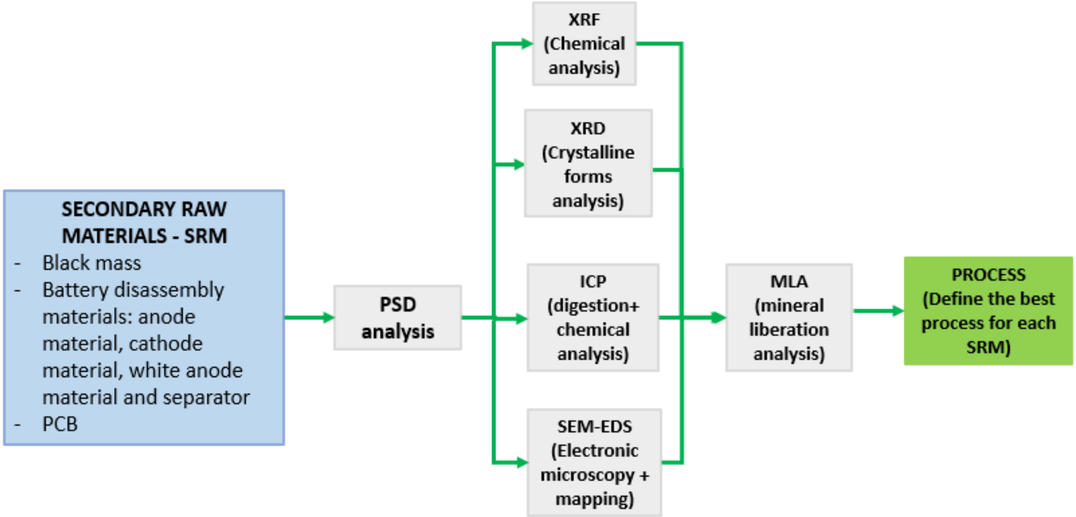

Figure 1. General scheme of the secondary raw material characterization.

Based on the characterization results, separation strategies will be discussed. The main purpose is to pursue three goals: first, achieving liberated metals concentration; second, graphite separation and third, metal oxide concentration. To achieve these goals, first of all, it is supposed to do liberation studies where the solid samples will be comminuted in the following top sizes: 5 mm, 1 mm, and 0.1 mm for metal liberation. Secondly, separation and concentration studies with two types of particle size ranges will be carried out: a) coarse (5 × 1 mm and 1 × 0.1 mm) using jigs, concentrating spirals, and concentrating tables. In addition, liberation studies to estimate the metal mass recoveries; b) fine particle range (-0.1 mm) using froth flotation studies and Multi-Gravity Separator (MGS) separation will be tested. Finally, physicochemical and mineralogical characterization, to monitor the trace of the added value and hazardous component contents, mass balance, and metals recovery based on the liberation and concentration studies will be done.

It is expected this project, specifically, is centered on the development and integration of separation processes based on mineral processing techniques to improve the management of e-waste. Obtaining concentrate by-products with this methodology will result in less chemical and energy consumption in the next steps (hydrometallurgy) which is a serious issue these days. The principal objective is to recover the potential added-value components by using selective methodology and different separation technologies based on the obtained results of liberation studies. We expect to reach our goals by implementing advanced mineral processing technologies for the valorization of industrial and e-wastes, to recover added value by-products, and thus promoting new strategies for recycling and reuse within the same industrial sector.

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