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Review

# Metallurgical recovery of metals from electronic waste: A review

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**Abstract**

Waste electric and electronic equipment, or electronic waste, has been taken into consideration not only by the government but also by the public due to their hazardous material contents. In the detailed literature survey, value distributions for different electronic waste samples were calculated. It is showed that the major economic driver for recycling of electronic waste is from the recovery of precious metals. The state of the art in recovery of precious metals from electronic waste by pyrometallurgical processing, hydrometallurgical processing, and biometallurgical processing are highlighted in the paper.

Pyrometallurgical processing has been a traditional technology for recovery of precious metals from waste electronic equipment. However, state-of-the-art smelters are highly depended on investments. Recent research on recovery of energy from PC waste gives an example for using plastics in this waste stream. It indicates that thermal processing provides a feasible approach for recovery of energy from electronic waste if a comprehensive emission control system is installed. In the last decade, attentions have been removed from pyrometallurgical process to hydrometallurgical process for recovery of metals from electronic waste. In the paper, hydrometallurgical processing techniques including cyanide leaching, halide leaching, thiourea leaching, and thiosulfate leaching of precious metals are detailed. In order to develop an environmentally friendly technique for recovery of precious metals from electronic scrap, a critical comparison of main leaching methods is analyzed for both economic feasibility and environmental impact.

It is believed that biotechnology has been one of the most promising technologies in metallurgical processing. Bioleaching has been used for recovery of precious metals and copper from ores for many years. However, limited research was carried out on the bioleaching of metals from electronic waste. In the review, initial researches on the topic are presented. In addition, mechanisms and models of biosorption of precious metal ions from solutions are discussed.


*Keywords:* Electronic waste; Metal recovery; Metallurgical process; Bioleaching; Biosorption; Precious metals

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## 1. Introduction

Waste electric and electronic equipment (WEEE), or electronic waste (e-waste), has been taken into consideration not only by the government but also by the public due to their hazardous material contents [1–5]. Currently, the main options for the treatment of electronic waste are involved in reuse, remanufacturing, and recycling, as well as incineration & landfilling. In many cases, electronic equipment which is no longer useful to the original purchaser still has value for others. In this case, equipment can be resold or donated to schools or charities without any modification. Reuse of end-of-life (EOL) electronic equipment has first priority on the management of electronic waste since the usable lifespan of equipment is extended on a secondary market, resulting a reducing of the volume of treated waste stream. Remanufacturing is a production-batch process where used products or cores, are disassembled, cleaned, repaired or refurbished, reassembled and tested to produce new or like-new equipments [6]. Recycling means the reprocessing in a production of the waste materials for the original purpose or for other purposes. Recycling of electronic waste involves disassembly and/or destruction of the EOL equipment in order to recover materials.

Incineration of electronic waste by traditional incinerator for municipal solid waste is also dangerous. For example, copper is a catalyst for dioxin formation when flame-retardants are incinerated. This is of particular concern as the incineration of brominated flame retardants (BFRs) at low temperature. It was estimated that emissions from waste incineration account for 36 tonnes per year of mercury and 16 tonnes per year of cadmium in the EU Community [1]. The hierarchy of treatment of e-waste encourages reuse the whole equipment first, remanufacturing, then recovery of materials by recycling techniques, and as a last resort, disposal by incineration and landfilling.

Recycling of electronic waste is an important subject not only from the point of waste treatment but also from the recovery aspect of valuable materials. The US Environmental Protection Agency (EPA) has identified seven major benefits, such as saving in energy and reduction in pollutions when scrap iron and steel are used instead of virgin materials. Using recycled materials in place of virgin materials results in significant energy savings [2,7].

From the point of material composition, electronic waste can be defined as a mixture of various metals, particularly copper, aluminum, and steel, attached to, covered with, or mixed with various types of plastics and ceramics [8]. Precious metals have a wide application in the manufacture of electronic appliances, serving as contact materials due to their high chemical stability and their good conducting properties. Platinum group metals are used among other things in switching contacts (relays, switches) or as sensors to ascertain the electrical measurand as a function of the temperature [9].

Table 1 gives examples of the metal composition of different electronic scraps from literatures. It is clear that electronic waste varies considerably with its age, origin and manufacturer. There is no average scrap composition, even the values given as typical averages actually only represent scrap of a certain age and manufacturer. Additionally, non-ferrous metals and precious metals contents have gradually decreased in concentration in scrap. This is due to the falling power consumption of modern switching circuits and the rising clock frequency (surface conduction). While the contact layer thickness in the ‘80s was in the region of 1–2.5 μm, in modern appliances today it is between 300 and 600 nm (gold wafer) [9].

The value distributions *Vi* for different electronic scrap samples (as shown in Table 2) were calculated by using the following