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RECYCLING OF WASTE CELL PHONES

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ABSTRACT - Recycling provides environmental benefits, such as energy savings, reduced volumes of waste, and reduced emissions associated with energy savings. Cell (mobile) phones are widely circulated in much of the world at the same time. Less than one percent of the millions of cell phones retired and discarded annually are recycled. Almost all the materials used to manufacture a cell phone can be recovered where metals, plastics, batteries, and packaging materials can be recycled and turned into new products. In this study, recycling technologies are summarized and, as a case study; the possibility of recovering valuable metals from waste cell phones by using acidic leaching was studied. The process steps include dismantling waste mobile phones, pre-processing to liberate the materials, and directing them to final treatment processes. In the leaching experiments, sulfuric, nitric, and hydrochloric acids are used. In the sulfuric acid leaching experiment, the effects of acid concentration, temperature, peroxide addition, and leaching periods on metal dissolution efficiencies are investigated. Leaching efficiencies of 97.9% Fe in 8 M H_2SO_4 solutions, 89% Pb, 100% Ni, 90.4% Co, and 4.1% Cu in 1M HNO_3 solutions, 100% Pb, and 100% Al in 4 M HCl solutions were found in one hour.

Keywords: Cell Phone, Recycling, Acidic Leaching.

INTRODUCTION

In today's society, it seems like everyone is glued to a cell phone. This results in about 100-120 million phones that are discarded every year [1]. With such high amounts, old cell phones have become the fastest growing form of electronic trash. This is causing a serious problem because electronic waste contains many hazardous materials. Within each mobile device, harmful chemicals and materials can contaminate soil and waterways, leading to long-term environmental effects that will eventually harm animal and human well-being [2]. More so because many people are to throw away their phones clogging landfills, polluting air and groundwater at an alarming rate. You can make a difference and stop the pollution by recycling your cell phone instead of carelessly discarding it. With innovative technologies, up to 80% of materials used in cell phones can be recycled and reused. Although cell phones consist of materials that differ from model to model and manufacturer to manufacturer, the guideline provides data characterizing the typical content of a mobile phone [3]. The substances identified

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include primary constituents, minor constituents and micro or trace constituents. Typically, about 40% of the weight of a mobile phone (including handset, battery and accessories) is plastics, while 20% is glass and 10% copper. Cell phones contain numerous metals, including expensive ones. The most important ones are copper, nickel, silver, gold, platinum group metals, cobalt, lithium, lead, tin, zinc, rare earth metals (REM), gallium, indium, iron, chromium, niobium, tantalum, and titanium. Table 1 lists the cell phone components most important that the metals they contain [4].

Table 1 Metals found in the most important parts of cell phones [4]

Metals	**Cell phone parts**
Chromium	Shield plates
Cobalt	Batteries
Copper	Connectors, printed circuit boards (PCBs), resistors, coils, speakers
Gallium	Printed circuit boards
Gold	Connectors, printed circuit boards
Indium	LCD displays
Iron	Resistors, shield plates
Lead	Capacitors, resistors
Lithium	Batteries
Nickel	Connectors, capacitors, resistors, shield plates, batteries
Niobium	Printed circuit boards
Palladium	Printed circuit boards
REE	Permanent magnets, LCD displays, speakers
Silver	Printed circuit boards , capacitors, resistors
Tantalum	Printed circuit boards
Tin	Printed circuit boards, capacitors, LCD displays
Titanium	Capacitors
Zinc	Resistors

Recycling Processes

Waste cell phones are useful sources of metals, including copper, gold, silver, and palladium, among others. The material recovery and recycling chain consists of the following main steps: collection, segregation (sorting out cell phones from other electronic wastes, separation of components, separation of accessories, battery removal from handset, manual or mechanical disassembly of other parts, recycling of batteries, recycling of accessories, recycling of handsets, shredding or shredding and separation of materials, sampling and analysis for the determination of the individual material composition, smelting, i.e. upgrading of metal contents, metals refining, i.e. separation and purification of metals to marketable products [3]. A prerequisite step in the material recovery and recycling of end-of-life cell phones is the manual separation of batteries, in order to minimize contamination of other materials in subsequent material recovery and recycling stages as well as to maximize recovery of the substances contained in the batteries. Manual separation may also be used to separate certain accessories from mobile phone handsets and, in some cases, plastic parts may be separated for recycling. Mechanical separation, including shredding, crushing and size reduction, followed by various separation techniques, can also be used.

Two main techniques are applied to recycle the PCBs of waste cell phones (WCP); pyro-metallurgical and hydrometallurgical processes. During the pre-processing phase of the material, the battery and hardware parts are dismantled manually and only the PCBs are collected [5]. Then, it is shredded and ground to make it ready for chemical processing. Hydrometallurgical technologies are predictable and controllable methods for material extraction [6, 7].

Smelting and Refining

The environmentally sound recovery and recycling of waste cell phones (excluding batteries and accessories) can be achieved through manual or mechanical component separation, followed by processing in specialized smelters [8]. After mechanical separation, the circuit board and other remaining parts are most efficiently recycled in a smelter, where valuable metals such as copper, gold, silver, and palladium are recovered. Direct smelting also recovers most metals, except iron, magnesium, and aluminum, while plastics serve as both a heat source and a reducing agent.

Smelting electronics, including cell phones, requires specialized equipment, yet many smelters lack proper pollution control. However, with adequate controls, metals can be safely recovered and recycled. Metal recovery from separated batteries involves smelting, which may release metal fumes and particulates, posing risks to workers and communities [3].

Following smelting, electro-refining, dissolution, and precipitation processes further purify the metals. If the resulting slag contains significant metal content, it is either returned to the smelter or processed through selective leaching and precipitation. Only a limited number of smelters and refiners worldwide possess the necessary material handling capabilities and pollution control systems for efficient metal recovery from end-of-life cell phones [3].

Hydrometallurgical processes

Among hydrometallurgical processes that can be applied, leaching is the leading technique based on the principle of solid component solubility by through of contact with leaching agent. Different factors can influence the leaching process, such as pH, temperature, concentration and oxidation–reduction potential (ORP). Hydrometallurgical processes use cyanide and/or strong acids such as aqua regia, nitric acid, sulphuric acid, and hydrochloric acid, ionic liquids, and bacteria to selectively dissolve metals and separate them from other substances [9]. Addition to these acids, a wide variety of reagent systems (e.g. iodide, ammonia, cyanide, thiourea and thiosulfate) in the presence of a suitable oxidant (e.g. ozone, H_2O_2, O_2, Cu(II), Cl_2 etc.) have been tested for leaching of metals from PCBs. Hydrometallurgical processes normally require firstly removal of plastics, and grinding to a small particle size with a high surface area.

Thus, hydrometallurgical process for cell phones will take place at later stages of selective metal recovery, to extract specific desired metals.

Plastic recovery

Plastics from cell phones have not been widely recovered as plastics yet, because few facilities can efficiently sort plastics into clean streams of a single type [3]. In smelters with appropriate flue gas treatment, plastics may be utilized in the metal recovering process, where they serve as a source of heat and substitute for other hydrocarbon fuels and as a reducing agent. If cell phone cases could be designed to be easily removed, and free of contaminating substances like paints, labels and metals, as well as collected in a reasonably large volume, the engineered plastics of cell phones, usually an acrylonitrile butadiene styrene-polycarbonate (ABS-PC), could be recycled with a positive economic value. Manual disassembling of mobile phones prior to precious metal recovery can produce reasonably clean streams of such plastic.

Land disposal

Land disposal of mobile phones may place them in contact with co-disposed acids, and, over an extended period, the substances that are soluble in those acids may leach out. If a landfill is not bound by an impermeable barrier, substances may migrate into ground waters, and eventually into lakes, streams, or wells, and raise a potential exposure to humans and other species. The greater risk of land disposal will be from direct ingestion of contaminants, contaminated soil and water in landfills that are not controlled [3]. If cell phones appear to be in good condition and can be reused, they may be redirected to refurbishment. One other method of recycling cell phones is to take the working parts of broken phones and combine them with the working parts of other used cell phones to make one ready-to-use cell phone [10]. The rebuilt phone can then be sent back into circulation without ever needing newly manufactured parts or natural resources.

MATERIAL AND METHOD

As a case study, this experimental study aims to investigate the possibilities of recovering the valuable metals in the PCBs of the waste (end-of-life/used) cell phones (Figure 1). It includes preparation, characterization, chemical analysis, and hydrometallurgical studies. Figure 1 presents an experimental flow sheet showing all processing steps. After dismantling old cell phones, we subjected the PCBs to size reduction using a shredder, then took cut samples for sieve analysis. Chemical analysis of the sample related to the size ranges are done. According analysis results, all metal contents, except Cu, Au, and Fe, do not change much with particle size range changes where Cu content decreases and Au content increases with decreasing size range and Fe content fluctuates without depending on size range [11].

Before leaching experiments, we conducted dissolution tests to determine the sample's metal content. For this purpose, samples were ground below 1.0 mm and then dissolved in aqua regia. An average weight loss of 53.11% was accepted as the total metal content.

EXPERIMENTAL RESULTS

Before starting leaching experiments, the waste cell (mobile) phone sample (collected from friends and families and supplied by Exitcom Recycling Ltd. Co.-Turkey) is ground under 1 mm in size, and in the experiments, effects of acid concentration, hydrogen peroxide (H_2O_2) addition in sulfuric acid media, leaching time, and acid type on metal dissolution efficiencies were studied [11]. Fe, Ni, and Co dissolutions increased with increasing acid concentrations, while Pb, Zn, and Al are not affected by acid concentration changes. There were no significant changes in metal dissolution efficiencies in terms of H_2O_2 addition. Increasing leaching time had an increasing effect on metal leaching efficiencies. Results of different acid applications are summarized in Table 2.

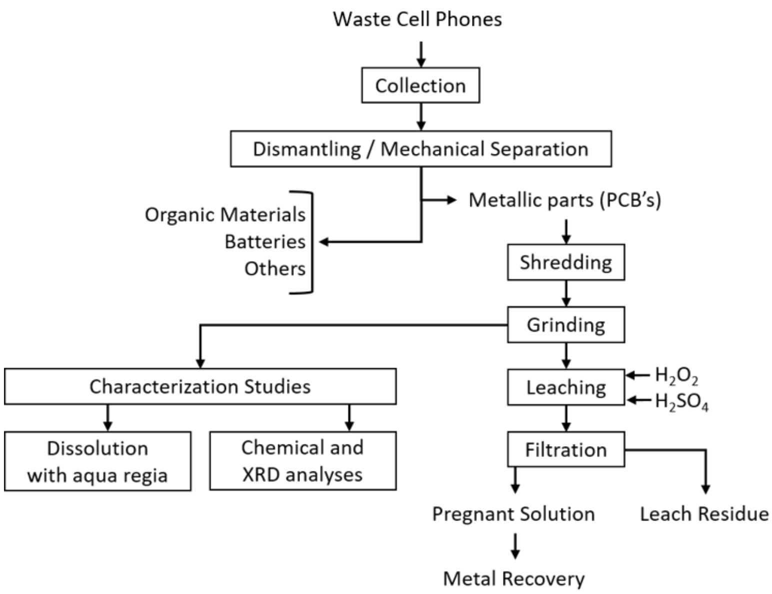

Figure 1 Experimental flow sheet for the recovery of metals from waste cell phones

Table 2 Effect of acid type on metal leaching efficiencies

Acid Type	Metal Leaching Efficiencies, %						
	Cu	Pb	Fe	Ni	Zn	Co	Al
1 mole/L H_2SO_4	0.09	0.54	31.45	3.30	7.69	36.09	61.09
8 mole/L H_2SO_4	0.16	3.32	97.90	7.75	9.59	61.78	24.02
8 mole/L H_2SO_4 + 20% of H_2O_2	0.15	4.06	88.65	15.09	9.30	62.25	36.69
1 mole/L HNO_3	4.13	87.98	21.84	100.00	25.66	90.40	37.20
4 mole/L HCl	0.74	100.00	48.84	17.69	18.80	77.57	100.00
8 mole/L HCl	0.85	100.00	49.25	17.61	19.97	71.36	100.00

In HNO_3 experiments, we observed higher leaching efficiencies for Co, Ni, and Pb; and in HCl experiments, higher efficiencies for Pb, Co, Al, and Fe while Cu leaching efficiency remained low in all cases, regardless of acid type. According to tables, 97.9% Fe leaching in 8 M H_2SO_4 solutions, 89% Pb, 100% Ni, 90.4% Co, and 4.1% Cu leaching in 1M HNO_3 solutions, 100% Pb, and 100% Al leaching in 4 M HCl solutions in one hour were found.

CONCLUSIONS

Less than one percent of the millions of cell phones retired and discarded annually are recycled. Almost all the materials used to manufacture a cell phone can be recovered where metals, plastics, batteries, and packaging materials can be recycled and turned into new products. Two main techniques are applied to recover metals from cell phones as pyrometallurgical and hydrometallurgical processes. As a case study, acidic leaching was applied. Experimental study yielded 97.9% Fe leaching in 8 M H_2SO_4 solutions, 89% Pb, 100% Ni, 90.4% Co, and 4.1% Cu leaching in 1M HNO_3 solutions, 100% Pb, and 100% Al leaching in 4 M HCl solutions within one hour. Therefore, for effective leaching of all metals, we recommend a sequential process using different acids. Precious metals can be dissolved by using cyanide, thiourea, and aqua regia. For metal recoveries from leach solutions, solvent extraction/ion exchange, precipitation, cementation, and electrowinning depending on metal types and compounds can be used.

REFERENCES

1. https://getrepowered.org/blog/importance-of-cell-phone-recycling/, 2025.
2. https://www.greentec.com/blog/e-waste-recycling-for-mobile-phones#the-e-waste-recycling-process-for-cell-phones-in-a-nutshell, 2025.
3. Project 2009. Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones, Mobile phone partnership initiative (MPPI) - Project 3.1 Guideline on Material Recovery and Recycling of end-of-line Mobile Phones, Revised and Approved Text, UNEP & Basel Consumption, March 25, 2009.
4. Buchert M., Manharrrt A., Bleher D., Pingel D. (2012) Recycling critical raw materials from waste electronic equipment, Darmstadt: Öko-Institut, 80 p.
5. Okwu, P.I., Onyeje, I.N. (2014) Extraction of valuable substances from e-waste. American Journal of Engineering Research (AJER). 3, (1), 299-304.
6. Cui, J., Zhang, L. (2008) Metallurgical recovery of metals from electronic waste: a review. J. Hazard Mater. 158 (2-3), 228-256.
7. Abdelbasir, S.M., Hassan, S.S.M., Kamel, A.H., El-Nasr, R.S. (2018) Status of electronic waste recycling techniques: a review. Environ. Sci. Pollut. Res. 25 (17), 16533-16547.
8. Wang, H., Zhang, S., Li, B., Pan, D., Wu, Y., Zuo, T. (2017) Recovery of waste printed circuit boards through pyrometallurgical processing: a review. Resour. Conserv. Recycl. 126, 209-218.
9. https://www.wastecare.com/Articles/Cell_Phone_Recycling.htm, 2025.
10. Arslan, F., Perek, K. T., Arslan, C., Çuhadar, İ. E., Altun, A. (2022) Studies on Acidic Leaching of Waste Mobile Phones, International Journal of Mineral Processing and Extractive Metallurgy, 7(2): 36-42.
11. E. Salinas-Rodrigez et al. (2022) Leaching of Copper Contained in Waste Printed Circuit Boards, Using Thiosulfate-Oxygen System: A Kinetic Approach, Materials, 15, 2354.