International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1306-1311 www.ijaem.net ISSN: 2395-5252

# Study on Physical Mechanical Treatment Process to Recover Metals from PCBS

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Submitted: 10-08-2022 Revised: 22-08-2022 Accepted: 24-08-2022

**ABSTRACT:**
This study was inspired by the growing concern about the manufacture of used electrical and electronic equipment worldwide (WEEE). Printed circuit boards, which are used in practically all types of electronic devices, are the core component of WEEE. Heavy metals found in PCBs have a negative impact on the environment. Particularly significant components of electronic equipment are PCBs, which make up around 3% of all e-waste produced. Typically, they are 40% metal, 30% organic, and 30% ceramic. On the other hand, some elements have value in addition, such as copper, gold, silver, iron, and aluminium. Due to the fact that it stops the extraction of new minerals, metal recovery helps preserve natural resources. In this study, the scanning electron microscope analysis was used to first identify the PCB element composition. The PCB was then crushed in a cutting mill and sieved into several grain size classes. After that, the non-magnetic portion underwent magnetic separation, gravity separation, and electrostatic separation. With gravity separation, the metal recovery for particles less than 0.6 + 0.3 mm and larger than 1.18 + 0.6 mm was good. The efficiencies attained in electrostatic separation were higher for smaller particle sizes (0.3 mm).

## I. INTRODUCTION:

Every day, massive amounts of electronic products, including computers and mobile phones, are discarded. Electronic trash is being produced at an exponentially growing rate due to the quick development of computing and other information and communication technology. E-waste management is a critical rising issue since between 20 and 50 million tonnes of electrical and electronic trash (WEEE) are created annually. The Global E-waste Monitor (2020) reports that an average of 7.3 kg of electronic garbage was produced per person globally in 2019, an increase of 9.2 Mt from 2014. Diverse materials found in the e-waste stream, including valuable materials like iron, steel, copper, aluminium, gold, silver, platinum, palladium, and plastics, need special handling and cannot be disposed of in landfills. These materials include hazardous substances like lead, polychlorinated biphenyls (PCBs), polybrominated biphenyls (PBBs), mercury, and polybrominated diphenyl ethers (PBDEs).

Accordingly, the goal of this research is to investigate new methods for recovering metals from printed circuit boards, with an emphasis on the physical-mechanical treatment recycling process, in order to produce a concentrate product. Characterizing the PCB, disassembling and grinding the board, and categorising the end products into various particle size classes comprised the process. After that, the metals were extracted by magnetic, gravity, and electrostatic separation.

## II. EXPERIMENT

2.1. Material: A printed circuit board contains a mix of conductive and insulating or dielectric layers. There are three main different types of PCB materials. The first is metal. Metals like copper, aluminum, and iron are generally used as the conductive layer in PCBs. Copper is the most popular. The second type of material used in PCB manufacturing is PTFE or Teflon and the third one is FR-4 is a glass-reinforced epoxy laminate sheet. It is a composite made of woven fibreglass cloth and a flame-resistant epoxy resin binder. FR-4 is the most commonly used material in printed circuit boards. Most of us have seen the green FR-4 board to which the electrical components are mounted, though it comes in other colours. It is a strong, lightweight, and somewhat flexible material. That is why most PCBs are “copper clad.” PCB typically consists of more than 20 different types of metals, divided into base metals such as copper, iron, nickel and tin; precious metals such as gold and silver and heavy metals such as lead and zinc and CRM, such as tantalum.
A review analysis of the values in mass percentage of some metals, obtained experimentally by several

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authors, was conducted. The metal content varies from 19% to 40% by weight and averages 34.

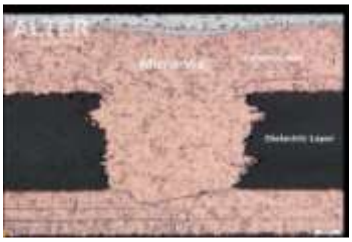

Figure 1. Microscopic layer of PCB.

2.2. Method: Following the identification of PCB constituent composition, the physical processing of the material was carried out, which began with the dismantling of the board and granulometric classification, followed by magnetic separation, electrostatic separation and gravity separation. In this study, the PWB consists of two thicker outer layers and eight thinner inner layers, all of them made from copper and interspersed with glass-reinforced plastic strands.

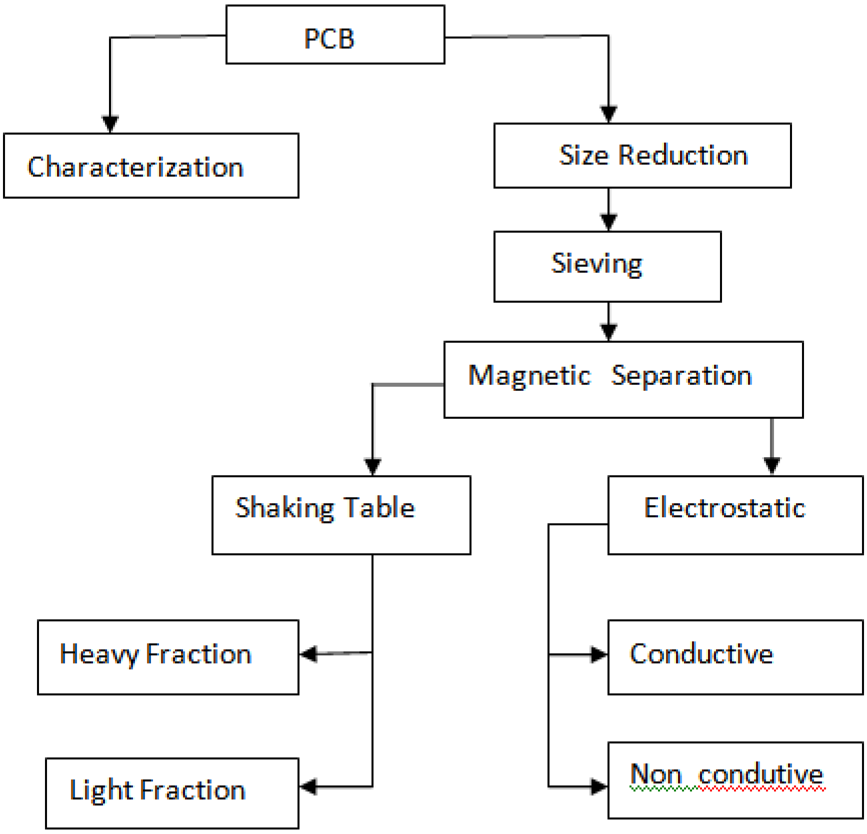


Figure 2.Process of flowsheet applied in this study.

As far as the PCB itself is concerned, it has about 23 aluminium capacitors, 89 tantalum capacitors, and 20 ceramic capacitors exceeding 13 volts each. It also has 6 transistors, 15 integrated circuits, and 5 different types of PCB connectors. In order to analyze the composition of the electronic components, SEM with EDS was used, which allows the identification of the elements that are present in the electronic components. It has been found that a significant number of metallic elements are present during this process: Sn, Pb, Au, Cu, Ni, Pd, Ag, Al, Fe, Ta, Ba, Mn. Figure 2 shows the process flowsheet of this work. During the dismantling phase of the project, the bulkiest components were removed from the structure. The central process unit and the liquid electrolytic capacitors that were removed were not carried on to the next steps. In order to provide enough feed for the RETSCH SM100 shredder utilised for comminution, the remaining portion of the board was eventually sliced into pieces of around 2.0 *3.5 cm. To achieve the granulometric categorization, the milled goods were sieved using the following sieve series: 0.6 mm, 0.3 mm, and 1.18 mm. Some

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metals can be separated from others via magnetic separation because of their magnetic susceptibility. This property controls whether a material will be attracted to or repelled by a magnetic field, classified it into three categories:
(i) Ferromagnetic, materials that have high magnetization; (ii) paramagnetic, those that weakly magnetize; and (iii) diamagnetic, are the materials that have negative magnetic susceptibility, which causes repulsion to the field. In every class fraction, the magnetic separation was done manually using a CoAlNi magnet held at a distance of 1.2 cm. This kind of separation can be used to separate printed circuit boards into a non-magnetic fraction that retains the remaining components and a magnetic fraction that is rich in iron and nickel. Based on the gravitational forces of a particle travelling through a fluid (water or air), gravity or density separation occurs. The use of the wet shaking table WEDAG 1933 is investigated in the current work for the recovery of the metals fraction present in the PCB scrap. With a small range of particle sizes and a significant variance in particle densities, this approach performs effectively. Shaking tables are inexpensive to buy and to operate. It is regarded as one of the most environmentally benign ways for processing minerals because no chemicals or heating are required. Concentrated, mixed, and tailing are the separation's end products. Following the passage, the products gathered in the various fractions were put into an oven set at 40 C to dry.

A Corona electrostatic separator has been used to perform electrostatic separation. When separating particles with different conductivities, the Dings Coronation separator is used. Corona electrostatic separation, which is the most popular because to its highly effective, ecologically benign, and cost-effective procedure, is employed because PCBs are made up of conducting metal layers and a non-conducting substrate. Two passages with a 20 kV voltage and a 30 Hz rotational speed were carried out.

After the physical enrichment processes were investigated and classified fractions were identified, samples were gathered for qualitative (visual) analysis using an optical microscope WILD. The grains are divided into the following categories for the visual evaluation: copper, metallic materials other than copper, fibre glasses, green plastics, and black plastics. Ultimately, the percentage of each product in the total is computed.

## III. RESULT AND DISCUSSION

### 3.1. Granulometric Separation

A sizable emission of fine particles was seen after the cutting mill. It can be seen that around 25% of the sample comprises particles smaller than 0.3 mm and that approximately 79% of the particles are less than 1.18 mm.

### 3.2. Magnetic Separation



Figure 3. Quantity in % of ferromagnetic metals a , magnetic separation results for the particle size class −0.3 mm, b.

The class that had the smallest size, 0.3 mm, also had the lowest value of separated ferromagnetic elements, 0.3%; this may be related to the class's low presence. Figure 3a shows that there is more ferromagnetic material in the +1.8 mm fraction than in the other fractions. This may be because ferromagnetic material is used in larger components like supports and tends to stay in the larger fractions due to its mechanical properties,

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which make it harder to grind than brittle materials like polymeric materials or ceramic.

Some metals, like copper, have been shown to exist in both the magnetic and non-magnetic fractions; nevertheless, because of its large concentration in WEEE PCB, it is pulled along with the iron and nickel particles (Figure 3b). Additionally, it is the outcome of particle aggregation, where the magnetic portion attracts non-magnetic elements. The entire family of ferrous metal products produced by magnetic separation is referred to as recovered product. Printed circuit boards contain a minor quantity of magnetic material, but it is vital to separate it before performing electrostatic separation since the magnetic force affects the particles and causes copper separation to be subpar.

3.3. Gravity Separation

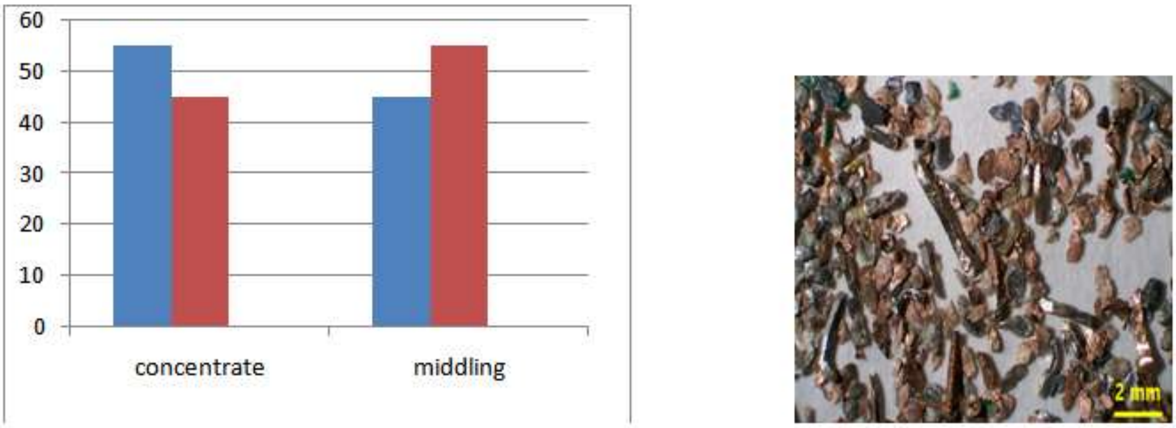


Figure 4. Weight of the products as percentage a; concentrate product for the particle size class −0.6 + 0.3 mm, b.

Non-ferrous material in two size fractions, 1.18 + 0.6 and 0.6 + 0.3 mm, was satisfactorily separated using a wet shaking table. Despite being within the working size, the grain size class 0.3 mm was spared this treatment since it was difficult to collect the separated products. Despite a potential efficient separation, the +1.18 mm class size was not tested since the amount of material was insufficient to carry out the procedure. For class sizes 0.6 + 0.3 mm and 1.18 + 0.6 mm, respectively, the sample that was subjected to the gravity separation weighed 280.70 g and 542.75 g. The acquired goods were weighed, and Figure 4a displays the results. Both separations were successful, yielding a concentrate product rich in metallic elements (Figure 4b) and an undesirable tailing product.

3.4. Electrostatic Separation

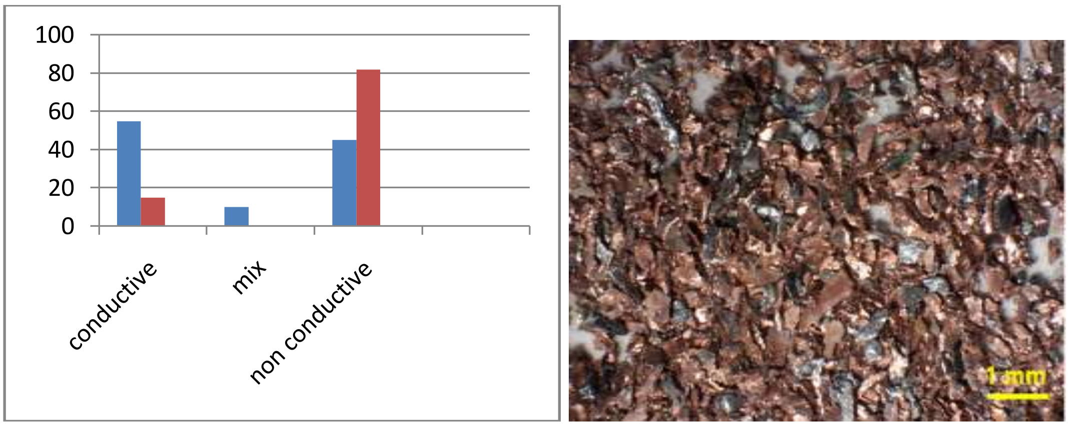


Figure5.weight of the product as percentage, a ,conductive product for the particle size class −0.3 mm, b.

According to Figure 5a, it is feasible to see a decrease in the metallic content for the granulometric class 0.3 mm. This is because this class mostly consists of fibrous material as a result of the laminate's fragility and its exposure to shear forces during comminution.

The conductive material produced for the class size 0.3 mm (Figure 5b) is made up primarily of metallic elements with the colour copper and a little amount with the colour silver. Despite containing a majority of metallic components that are copper in colour, the combined product also contains polymeric components. The appearance of the non-conductive product is dominated by greenish polymeric pieces. The majority of the class size +1.18 mm's conductive product is made of fibres, and the metal components are bonded using resins. Flakes and filaments of metallic elements were discovered, with the first being more prevalent. Additionally, it was noted that they come in shades of copper, gold, and silver. The mixture consists primarily of metallic and non-metallic components. Additionally, the non-conductive product has a design that primarily consists of fibreglass and polymeric fragments in the colour black.

### 3.5. Metal Recovery Balance

Since copper is a precious metal and is heavily present in PCBs, making it the primary target of separation, it was determined to evaluate the efficiency of the metal recovery of the separation process as a function of the percentage of copper. The image fields were analysed for the copper particles and the other materials, and the particles that belonged to the same particle group were counted. The numerical distribution of the percentages for the various fractions and products was established. For each experiment conducted, the grains were separated into three different particle groups: non-metals (NM), metals other than copper (Me), and copper (Cu). The entire ferrous product that was produced via magnetic separation is regarded as recovered. The concentrate product used in gravity separation is used to gauge the amount of metals recovered. In contrast, the conductive and mixed products are the metallic fraction recovery for electrostatic separation.

For iron and its alloys, it has been observed that magnetic separation yields a good metal recovery; only in the finer fractions, a small percentage of non-ferrous components are dragged and continue to be attached to the iron grains. The metal recovery in the gravity separation produced positive results and similar percentages in the two granulometric classes (64% for the fraction +0.6-0.3 mm and 67% for the fraction +1.18-0.6 mm), demonstrating an effective method for this range of particle size. For these fractions, there is a metal loss of 11% and 15%, respectively. Due to the difficulties of applying the shaking table and the low metallic content (heavy product), electrostatic separation is thought to be the best method for the finer particle size class. Even if the electrostatic separation for the presence of copper in the granulometric class +1.18 mm indicates to be reasonably good, there is a considerable presence of plastics and glass fibre embedded to copper grains, making a product low in concentration. It is also conceivable to draw the conclusion that 78% of the other metals and 88% of the copper might be recovered.

## IV. CONCLUSIONS

In order to reduce undesired materials and reduce wear on the comminution equipment, it is advantageous to do pre-processing on the boards as a first step. This involves eliminating some components. The traditional procedures of disassembling, fragmenting, and separating the material into several granulometric classes are implied by the physical-mechanical processing. The board's imbedded metals were able to be freed by the comminution process. The individual elements' distinctive mechanical behaviour, which differed from one another, gave the fragmented particles the qualities they needed to be separated later. Although the items were characterised using a qualitative method, the products' performance in terms of the presence of metallic components was effective. The use of magnetic separation proved to be effective since it allowed iron to accumulate in the magnetic fractions (85–99%), and it can be deduced that the PCB's large particle size fraction contains the highest concentrations of iron. Due to operational considerations and volumetric availability, respectively, the finest and coarsest class fractions were omitted from the gravity separation. A good metal recovery is demonstrated by the results, which are 60% for the class size + 0.6-0.3 mm and 63% for the class size + 1.18-0.6 mm. For the coarsest particle size fraction and the finest, the proportion of conductive material (Cu) was 45% and 79%, respectively. This shows both the effectiveness of the electrostatic separation, which predominantly concentrated this element, and the reduced size which allowed the liberation of this metal. A metal concentration was produced by this process, making it simpler to isolate the constituent elements using metallurgical techniques.

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