

## Chemical Separation of Copper from the Printed Circuit Board of Dead Electronic Gadget Cell Phone Set (Samsung J-2)

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### Abstract

The increasing popularity of electronic devices among the public has increased electronic waste (e-waste). Most electronic devices become obsolescent after their use and generate hazardous chemicals if not disposed properly. The conducting networks in all electronic gadgets are made up of Copper (Cu) that can be retrieved by the chemical segregated method. In this experiment, a hydrometallurgical technique was used as acid leaching, selective recovery of Cu from the leachate using the group separation methods and measured the Cu metal separated from the acid leach. 5.05 g CuO is extracted which is equivalent to 4.03 g of Cu from the Samsung J-2 cell phone having an initial weight of 18.33 g PCBs. Atomic Absorption Spectroscopy (AAS) and Energy Dispersed X-ray analysis (EDX) techniques are used for the characterization of the extract. The recovery of Cu from this technique is about 93 % of the PCB board of Samsung J-2 mobile set.

**Keywords:** E-waste; PCBs; Copper; AAS; EDX;

### Introduction

Old electronic devices that are no longer in use are referred to as electronic waste (e-waste), such as computers, phones, televisions, and even appliances [1]. It is also known as waste electrical and electronic equipment (WEEE), which is a major supplementary source of crucial and basic metals. The increasing digitalization of electrical devices and machine equipment with electronic circuit boards, after the end of an appliance's life, becomes unsafe waste that needs to be handled satisfactorily. Over the past few years, the global market for electrical and electronic equipment (EEE) has seen remarkable growth, leading to a significant increase in the disposal of electronic gadgets [2,3]. The amount of e-waste that is officially recorded as collected and recycled has increased from 8 billion kg in 2010 to 14 billion kg in 2022, although this accomplishment is eclipsed by the

overall rapid growth in e-waste [4].

Manufacturing a bulk amount of EEE needs a huge amount of non-renewable resources, including various precious, toxic, rare earth metals, and many more [5]. E-waste is easily recyclable, clean, and non-homogenous waste; problems arise when garbage is composed of various elements [6]. Modern electronic gadgets contain up to sixty different elements often combined into complex alloys and numerous compounds [7]. These components are used in minute quantities to create essential components like microchips, printed circuit boards (PCBs), permanent magnets, and display monitors [8]. Discarded PCBs hold significant value due to the presence of recoverable metals. All EEE comprises PCBs of a variety of sizes, nature, and arrangements [9,10]. These

ingredients are a complicated mixture of metals, polymers as well as ceramics [11]. Among the WEEE, waste mobile phones and waste PCBs are identified as highly hazardous by the U.S., European Union, China, and other nations [12,13].

In addition to valuable metals such as Palladium (Pd), Gold (Au), Platinum (Pt), and Silver (Ag), PCB contains extremely high concentrations of metals including Iron (Fe), Copper (Cu), Nickel (Ni), and Aluminum (Al). Recovering metals from discarded PCBs is a challenge. Traditional methods for processing WEEE use either hydrometallurgy or pyrometallurgy, but both have certain drawbacks and restrictions [14]. After being processed at a WEEE treatment facility, the composition of discarded PCB reveals a heterogeneous material mixture. Studies indicated a weight distribution of approximately 38.1 % ferrous metals, 16.5 % non-ferrous metals, 26.5 % plastic, and 18.9 % miscellaneous materials [15]. This highlights the complex nature of PCBs, indicating the extreme need for selective separation techniques for efficient metal recovery. Prioritization of recoverable metals is crucial for sustainable e-waste management strategies. Research suggests that Au holds the highest recovery priority due to its high economic value and scarcity [16]. Cu, Pd, Al, Sn, Pb, Pt, Ni, Zn, and Ag follow in the descending order of prioritization. This ranking scheme is likely to be influenced by a combination of factors, including metal value, the environmental impact of extraction, and the technological feasibility of recovery from the complex PCB [17].

Cu, the leading metal in PCB, shapes the conducting layer used for electrical connections [18]. According to Hadi et al. (2015), there is a positive correlation between the conductor

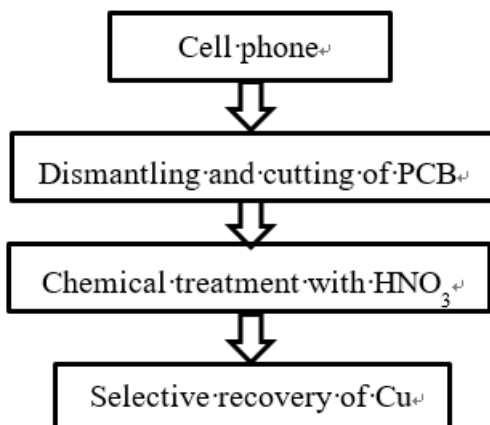
current capacity and the number of layers in a PCB and its Cu concentration. PCBs have Cu contents ranging from 15 % to 35 % by weight [19]. The main objective of this paper is to discuss the simple laboratory technique used to separate Cu from the electronic gadget cell phone set (Samsung J-2) and to explore an environmental friendly and sustainable way for recovering Cu.

## **Materials and Methods**

The analytical grade chemicals were used for all the experiments without further purification. Nitric acid (HNO<sub>3</sub>), Sodium hydroxide (NaOH), sulphuric acid (H<sub>2</sub>SO<sub>4</sub>), hydrochloric acid (HCl), ferrous sulfide (FeS), ammonia (NH<sub>3</sub>), and silver nitrate (AgNO<sub>3</sub>) were obtained from Merck Life Science Private Limited. Absolute alcohol (ethanol) was supplied by Bengal Chemicals and Pharmaceuticals Limited. Barium chloride (BaCl<sub>2</sub>) was outsourced from Qualigens Fine Chemicals. Distilled water was prepared in the laboratory of the Research Centre for Science and Technology (RECAST). Deionized water was received from Nepal Solar Thermal and Clean Energy Power Private Limited, Kritipur, Nepal.

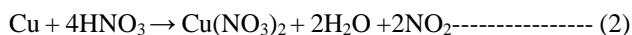
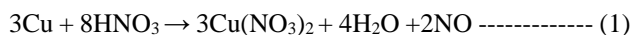
The main raw material for this work Samsung J-2 mobile phone was provided by Doko Recyclers. First of all, the plastic cover at the back side was unscrewed using a screwdriver. The battery and visible components were carefully removed manually. The readily accessible items and the PCB were carefully separated. The waste PCB separated (WPCB) was physically cut into pieces, then a grinder was used to break it into tiny pieces. Cu-containing components were separated from the PCBs by different chemical methods. Experiments were carried out in a beaker at normal room temperature following the work procedure described stepwise in the flow chart

shown in **Fig. 1**



**Figure 1:** Flow diagram of work plan

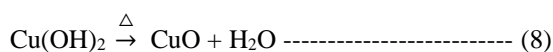
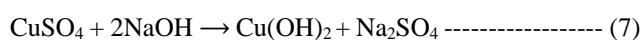
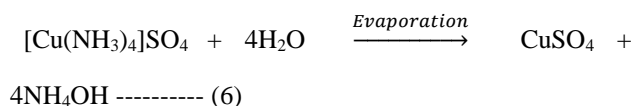
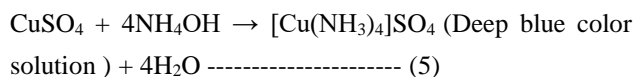
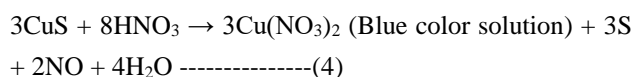
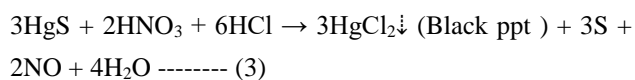
The crushed WPCBs were added to 3N HNO<sub>3</sub> solution in the ratio of 1:10. During the leaching of the crushed boards in an aqueous HNO<sub>3</sub> solution, Cu was reduced to Cuprous nitrate (Cu(NO<sub>3</sub>)<sub>2</sub>) as per the reaction shown in equations 1 and 2.



Likewise, other metals present in PCBs also react to HNO<sub>3</sub> to form metal nitrate [19]. So, the leach liquor contains a mixture of all the metals in its nitrate form. A small portion of the diluted liquor was sent to the laboratory to perform Atomic Absorption Spectroscopy (AAS). The common metallic ions are divided into several groups, based on their solubility product [20]. Metal ions belonging to any specific group are precipitated by a special group reagent. Hence, using a specific reagent, the metallic ions are separated into different groups as their precipitates [20]. Initially, dilute hydrochloric acid was added to eliminate group I metal ions such as Silver (I) ion (Ag<sup>+</sup>), Mercury (I) ion (Hg<sub>2</sub><sup>2+</sup>), and Lead (II) ion (Pb<sup>2+</sup>), their absence was confirmed by a lack of precipitates. Subsequently, group IIA metal ions such as Mercury (II) ion (Hg<sup>2+</sup>), Lead (II) ion (Pb<sup>2+</sup>), Bismuth (III) ion (Bi<sup>3+</sup>), Cadmium (II) ion (Cd<sup>2+</sup>),

Copper (II) ion (Cu<sup>2+</sup>) were precipitated by passing H<sub>2</sub>S gas through a heated solution resulting a dirty black/brown residue. After complete precipitation and washing-drying, a small amount of sample was observed Energy Dispersed X-ray Analysis (EDX).

Analysis of group IIA metal ions was done for selective recovery of Cu [20] from the precipitate. HNO<sub>3</sub> was used to dissolve the sample, potentially creating a mercury precipitate as shown in equation 3. Lead absence was confirmed by the lack of precipitation with H<sub>2</sub>SO<sub>4</sub> and ethanol (C<sub>2</sub>H<sub>5</sub>OH). Excess NH<sub>3</sub> was then added, and the resulting blue solution indicated the presence of Cu (no precipitate for Bismuth) shown in equations 4 and 5. In this way, all the metal ions like Hg<sup>2+</sup>, Pb<sup>2+</sup>, and Bi<sup>3+</sup> were eliminated from the precipitate. Excess NH<sub>3</sub> was removed by evaporation shown in equation 6, then the solution was neutralized with NaOH to precipitate and isolate Copper hydroxide (Cu(OH)<sub>2</sub>) shown in equation 7 which was calcinated in the muffle furnace at 500°C for 1 h. Finally, Cu was obtained as Copper oxide (CuO) as shown in equation 8. A small amount of the sample was again sent to the laboratory to perform EDX.



### Characterization Methods

AAS was used for the quantitative

measurement of chemical elements, carried out with the help of an atomic absorption/emission spectrophotometer (Model No.: AA201, Manufacturer company: Chemito Instrument Private Limited, India). The calibration curve for the standardization was plotted with standard  $\text{CuSO}_4$  solution 1, 3 and 5 ppm. The experiment was performed in Enviro- Chem Private Limited, Battispatali, Kathmandu. EDX was used for the elemental analysis or chemical characterization of a sample, carried with the help of an Energy Dispersive X-ray Fluorescence Spectrophotometer (Model No. : EDX-8000, Manufacturer company: Shimadzu, Japan). The experiment was performed in the Customs Department, Tripureshwor, Kathmandu.

## Results and Discussion

### Gravimetric Recovery of Copper from WPCB

Almost all base metals along with some precious metals dissolved in the 3N  $\text{HNO}_3$  solution [19]. Cu was selectively extracted from the leached solution using a variety of techniques, including group separation methods based on common ion effects and solubility products as described in the experimental section [20]. At last, 5.05 g  $\text{CuO}$  was obtained from the Samsung J-2 cell phone (83.66 g) having 18.33 g PCBs which is equivalent to 4.03 g of Cu. The final product of this research work is shown in **Fig. 2**



**Figure 2:** Copper oxide in a crucible

### Quantitative and Spectroscopic Measurement for Cu in WPCB

AAS is a sensitive and practical technique for identifying dissolved metal ions such as Cu. The absorption peaks in an aqueous sample are anticipated to remain discrete and non-overlapping, preventing other metals from interfering with the Cu ion signal. Establishing the relationship between the measured absorbance and the analyte concentration required standards with known analyte content. The absorbance of the standard solutions of  $\text{Cu(II)}$ , prepared in the range of 1.0–10.0  $\mu\text{g mL}^{-1}$ , was measured by direct aspiration into the atomic absorption spectrometer [21]. All experiments were performed in triplicate and the mean of results was used to draw the calibration curve. To indicate that the analytical signal for the standard solutions in water and that in the chloroform-ethanol mixture were equal, an investigation was carried out [22]. The leachate contains 245499.18 ppm Cu (245.5 g/kg). The single set of WPCB (18.33 g) was found to contain 4.5 g of Cu which is found to be almost equal to quantize in the gravimetric method.

### Elemental and Percentage Composition of Cu in Cu-Precipitate

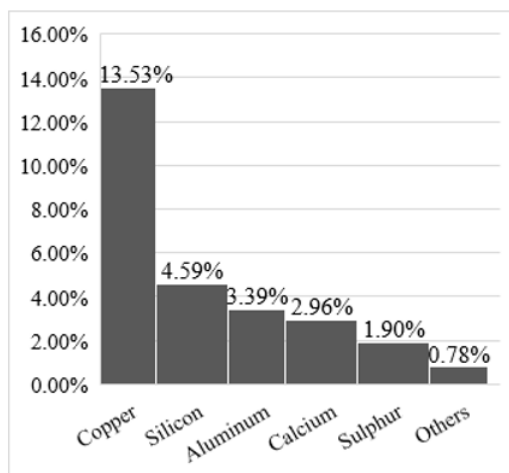
EDX investigation shown in **Fig. (3 & 4)** relies on the interaction of some source of X-ray excitation and a sample. Two samples were sent for the EDX characterization.

#### Elemental Analysis of Cu-precipitate (post-group I)

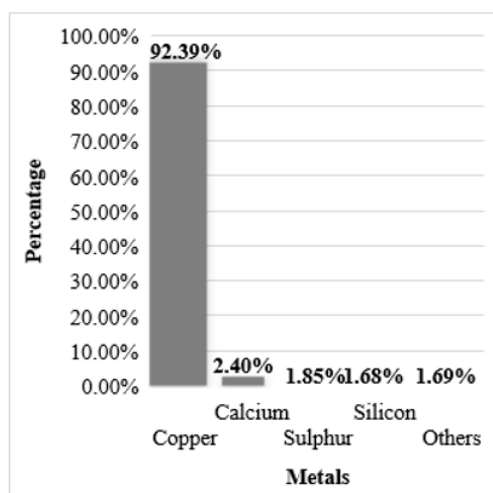
The percentage of different metals present in the composite after removing group I metal ions ( $\text{Ag}^+$ ,  $\text{Hg}_2^{++}$ ,  $\text{Pb}^{++}$ ) is shown in Fig.3 where other elements such as Silicon (Si, 4.59 %), Aluminium (Al, 3.39 %), Calcium (Ca, 2.96 %), Sulphur (S, 1.90 %), Potassium (K, 0.44 %), Iron (Fe, 0.20 %), Titanium (Ti, 0.08 %), Nickel (Ni, 0.03 %), Chromium (Cr 0.03 %, and Manganese

(Mn, 0.01 %) found to be in various percentage along with highest Cu (13.53 %) content.

### Selective recovery of Cu



**Figure 3:** Bar graph showing the different percentages of metals present in the sample after removing metal ions of group I



**Figure 4:** Bar graph showing the different percentages of metals present in the final Cu extract

The EDX data observed after selective recovery of Cu from the precipitate observed for Gr. IIA is shown in **Fig.4** where Cu content is significantly high 92.39 % and other metallic components were observed in very fewer amounts such as Ca (2.40 %), S (1.85 %), Si (1.68 %), along with negligible amounts of Chlorine (Cl) 0.71 %, K (0.12 %), Fe (0.29 %), Ti (0.06 %), Ni (0.15 %), Lead (Pb, 0.02 %), and Terbium (Tb, 0.34 %). The EDX data showed the appreciable purity of Cu extracted from WPCB

following the methodology mentioned in the experimental section. For further purification, the CuO powder can be heated with a reducing agent like hydrogen gas (H<sub>2</sub>) or carbon monoxide (CO) to convert CuO to Cu metal or electrorefining can be employed. This electrorefining involves depositing Cu onto a cathode from a Cu salt solution.

### Conclusions

Cu was recovered from the WPCB of a Samsung J-2 cell phone set in its oxide form in the laboratory by using simple chemical methods. The following conclusion can be drawn from the results this study presents:

- Cu is separated (4.03 g) from 18.33 g of WPCB of Samsung J-2 following a general chemical procedure in the laboratory.
- The absorption spectroscopy also confirmed the almost similar content of Cu in the leachate (4.5 g) for the WPCB of the Samsung J-2
- The elemental composition confirmed the purity of the extracted Cu as 92.39 %, which can be used after various processes of purification methods such as polling, melting electrolysis, and many more.

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The authors thank Doko recyclers for providing raw materials, Enviro- Chem Private Limited, and Customs Office for the AAS characterization and elemental analysis (EDX) respectively and further acknowledge Dr. Rameshwar Adhikari, RECAST for providing laboratory facilities to complete research work.

### Author's Contribution Statement

**Geeta Aryal:** Methodology, Formal analysis, Data curation, Writing-original draft preparation, Writing-review  
**Joyti Giri:** Conceptualization, Writing-review and editing, Supervision

## Conflict of Interest

The authors do not have any conflict of interest throughout this research work.

## Data Availability Statement

The data supporting this study's findings are available from the corresponding authors upon reasonable request.

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