

## Recovery of Nickel from Waste Printed Circuit Boards of Personal Computers

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**Abstract :** Present study reports, the application-oriented process for recovery of nickel from printed circuit boards (PCBs) of scrap personal computers. The PCBs were initially depopulated, crushed, pulverised and beneficiated to get the metallic concentrate. The concentrate was further processed by hydrometallurgical leaching and solvent extraction processes to extract nickel and copper. At first, leaching studies were carried out in sulphuric acid at different process parameters such as acid concentration, reaction time, temperature etc., to dissolve the metals. Results shows that 99% Ni and Cu were leached in 20% H<sub>2</sub>SO<sub>4</sub> at 75°C for 2 h maintaining the pulp density 100 g/L in presence of 20% H<sub>2</sub>O<sub>2</sub>. The obtained leach liquor was further processed by solvent extraction technique to separate the Cu and Ni. It was found that 99% Cu and Ni were selectively extracted with LIX-984 N at pH: ±2.5 and ±4.5, respectively. Electrolysis, evaporation and crystallisation processes could be used to obtain the pure metal and its salt from the pure metallic solutions.

**Keywords:** PCBs, Sulphate Media, Nickel, LIX 984 N, Solvent Extraction

### 1. INTRODUCTION :

Nickel is widely used in the electronic equipments such as printed circuit boards of personal computer, mobile phone, television etc., due to its corrosion resistance and ability of conduct electricity [1]. These electronic items become obsolete after reaching its end-of-life resulted in the generation of huge amount of discarded e-waste, which contains valuable metals [2]. It has been reported that 53.6 million tons of e-waste were generated in year 2019 and it is expected to produce 74 million tons in 2030 [3]. Hence, it has been considered as one of the potential resource for recovery of metals like copper, nickel, lead, tin, etc. [4]. The waste PCBs typically contains 30% metals and 70% non-metals [5]. The PCBs contains metallic elements such as Cu (20%), Pb (2%), Sn (4%), Ni (2%), Fe (8%) and Zn (1%) as well as some precious metals like Ag (0.2%), Au (0.1%) and Pd (0.005%) [6]. Presently, only 10 to 20 % e-waste were recycled by the formal sector; whereas rest of the e-waste treated by informal sectors which may cause serious environmental threat [7]. Therefore, it is necessary to develop a sustainable environmental friendly process for recovery of metals from e-waste.

Many authors have been reported for the recovery of copper from waste PCBs. Zhou et. al reported pyrometallurgical extraction of copper from waste PCBs at 1200°C [8]. 99% of Cu was extracted along with the other elements (Au, Ag, Pb). In addition, metals value may also be waste during the pyromatalluegical

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processes. During the pyrometallurgical process evolution of toxic gases occurs which is environmentally not acceptable. Therefore, hydrometallurgical technique has been applied to extract the metals from waste PCBs. Subsequently, hydrometallurgical studies have been reported to recover metals from waste PCBs.

Oh et. al. [9] reported that 95% extraction of Cu along with Ni and other metals was accomplished from metallic mass of computer PCBs by leaching with 2M H<sub>2</sub>SO<sub>4</sub>, 0.2M H<sub>2</sub>O<sub>2</sub>, 85°C for 12 h. Additionally, Birloaga and Yang explained the parameters of leaching such as effects acid concentration and H<sub>2</sub>O<sub>2</sub> concentration, leaching time, temperature, and solid-to-liquid ratio, to optimise the parameters [10,11]. Furthermore, nitric acid leaching was reported at room temperature for 2 h maintaining 20 g/L pulp density [12].

Subsequently, Kumari et al [13] reports pressure leaching of crushed PCBs at 29 bars oxygen pressure with 150°C temperature, 90 min, 100 g/L pulp density in 2.4 M H<sub>2</sub>SO<sub>4</sub>. Under these conditions, it showed Cu-10.76 g/L, Ni-0.38 g/L, Fe-2.55 g/L and Pb-0.07 g/L in leached liquor of PCBs [13]. Jha et al reported solvent extraction of Ni from the leach liquor of waste PCBs. 91.6% of nickel recovered by using 5% D2EHPA at pH 3.48 [14]. Panda et al. reports complete separation of copper and nickel from nitrate leach liquor waste ICs of PCBs. 99.99% of Cu was extracted at pH 2.97, by 20% LIX 984 N while Ni remain in the raffinate [15]. Over 96% Ni extracted in form of NiSO<sub>4</sub> after removing Co from Li-ion and Ni-metal Hydride batteries. By 1% LIX 84IC, Ni recovery was enhanced as 5.20 to 95.30% in pH 3.67 to 5.48 at O/A ratio 1:1 with time 15 min from leached liquor of PCBs [16].

In the view of above mentioned aspects, the present study reports the novel process for selective extraction of Cu and Ni from discarded PCBs of personal computer. Initially, PCBs were pre-treated by mechanical and flotation process to get the metallic concentrate. Thereafter, leaching studies were carried out at different process parameters such as acid concentration, time, temperature to optimise the condition for maximum dissolution of metals. Subsequently, solvent extraction studies were also carried out with LIX-984 N at different parameters to selectively extract the Cu and Ni from leach liquor of PCBs.

## **2. EXPERIMENTAL**

### **2.1. Materials**

Different Scrap PCBs collected from various sources then PCBs were depopulated and segregated the electronic components accordingly and crushed and ground mechanically in CSIR-NML, then followed by Sulphuric Acid, Hydrogen Peroxide for leaching, LIX 984 N, NaOH. All reagents and chemicals were supplied by E. Merck, Mumbai, India.

### **2.2. Methodology**

#### **2.2.1. Pre-treatment process**

Discarded CPUs were collected from various sources after that dismantling small components were classified accordingly. Manually segregated PCBs were collected and depopulated using hot gun (Make: DEWALT) and carried to shredding in scutter crusher or shredder slowly for 5 minutes further the crushed materials of PCBs were treated in pulveriser for another 5 minutes to get the materials into fine particles to increase the efficiency of the leaching process. After Pulverizing the samples, density separation or gravity separation of sample were

done for 20-25 minutes to separate metallic and non-metallic fractions on basis of their particle density. Here, metallic fractions were found nearly about 28-30% (290g), and the rest of non-metallic epoxy and plastic materials having 70% (710g). The composition of the metallic proportion of PCBs was greater in copper followed by tin, nickel, zinc, and lead in little bit concentrations (Table 1).

**Table1. Metallic composition (wt.%) of PCBs concentrate.**

Cu	Ni	Zn	Pb	Sn
95.2	1	0.4	0.7	1.5

### 2.2.2. Leaching method

Leaching experiment was conducted in a hot plate-mounted, capacity of two-liter, three-necked, round-bottom leaching reactor with a condenser and temperature control sensor that stirred continuously at a fixed rpm. Several process variables were viz. time, temperature, pulp density, and stirring rate were tuned in relation to leachant concentration. In addition, a specific weighted quantity of metallic concentrate was used as the leaching agent along with sulfuric acid ( $H_2SO_4$ ) and hydrogen peroxide ( $H_2O_2$ ). The sample was added gradually while stirring continuously at a set rpm until the solution temperature reached the appropriate level. Using 20%  $H_2SO_4$  and 20%  $H_2O_2$  at 75°C for 2 h, the Ni metal and other impurities in the concentrate were leached by maintaining a pulp density of 100 g/L for maximum dissolution of metals.

### 2.2.3. Solvent extraction method

Studies on solvent extraction at the bench scale were conducted by combining 50 mL each of the organic extractant and leach liquor using a mechanical stirrer for a predetermined amount of time. For stripping 10% (v/v) sulphuric acid were used, as in the part solvent extraction, the various studies were carried out at different pH, O/A ratio and strippent concentration

### 2.2.4. Analytical Method

The metal was recovered in an acidic aqueous phase and analyzed in the conventional method by using AAS (Perkin Elmer model, Analyst 200; USA). To analyze the copper concentration used wavelength is 324.8 nm, and nickel at 232 nm. The metal concentration in the organic phase was calculated by deducing the metal concentration in raffinate from the metal concentration of the initial solution. The pH of the solutions was measured using pH 700 Eutech instruments.

## 3. RESULTS AND DISCUSSION

### 3.1. Leaching studies

Leaching experiments were carried by varying the sulphuric acid from 10% to 20% at 75°C in presence of 20% (v/v)  $H_2O_2$  for 120 min to leach the metals from concentrate. Results shows that (Figure 1.) leaching efficiency of Ni as well as Cu increases with increase in acid concentration. Approximately, 78% Ni and 76% Cu were leached in 10%  $H_2SO_4$  at 75°C in 120 min while 99% Cu and Ni leached in 20%  $H_2SO_4$ . It may be due to

increase in the movement of  $H^+$  ions through the metallic concentrate particle boundaries that caused improvement in leaching efficiency with increased of acid concentration. The leaching reaction of copper and nickel with sulphuric acid in presence of hydrogen peroxide is presented in eq. 1 and 2.

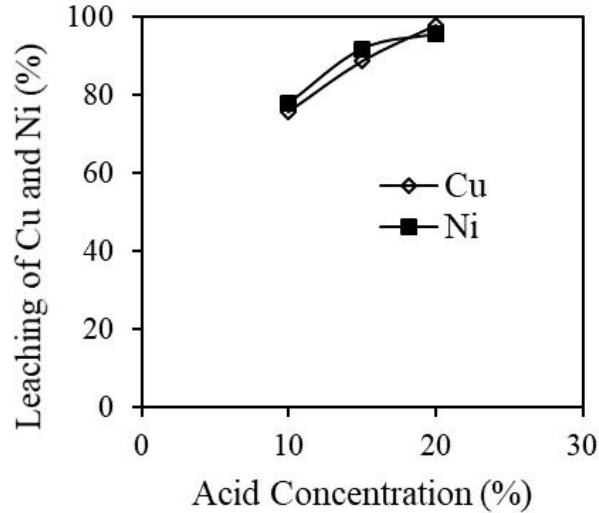


Figure 1. Effect of Acid concentration on leaching of Cu & Ni from PCBs [Solid 10 g metallic concentrate; Temperature:75 °C; Time: 120 min, Oxidant:  $H_2O_2$ ]



### 3.2. Solvent extraction studies

#### 3.2.1. Effect of pH on Cu and Ni extraction

To optimise the equilibrium pH for selective extraction of Cu and Ni from leach liquor of PCBs, studies were carried out using LIX-984 N in a range of pH 1 to 4.8. Result (Figure 2) shows that the extraction of Cu were increases with increase in eq. pH and it was found that 99% Cu extracted at eq. pH ~2.5 maintaining O/A: 1/1 in 15 min; whereas, negligible amount of Ni was co-extracted. Further eq. pH was increased to extract Ni from the raffinate left after the extraction of Cu. It was observed that extraction of Ni increases from 19% to 99% with increase in eq. pH from 3.5 to 4.5 at O/A ratio: 1/1 in 15 min (Figure 2). The loaded organic was stripped with dil.  $H_2SO_4$  solution to get the pure solution of Cu and Ni, respectively. The generalized equation for Cu and Ni extraction is presented in equation 3 and 4.



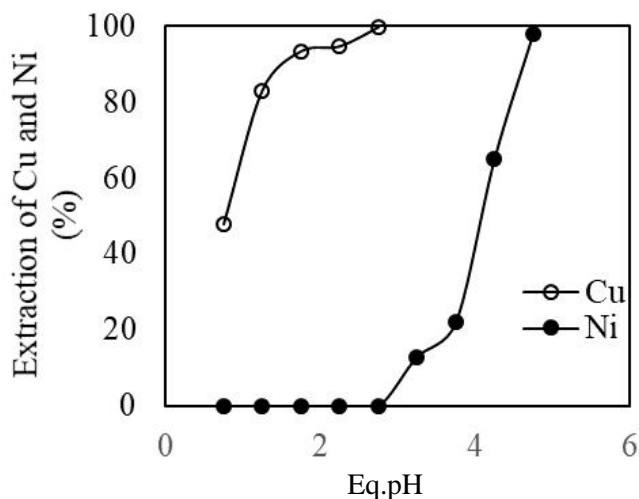


Figure 2. Effect of pH on Cu & Ni extraction.

[Leach liquor of PCBs; Extractant: LIX-984N; eq. pH: 1 to 4.5; Time : 15 min]

### 3.2.2. Effect on Strippent concentration on Ni stripping

Loaded organic was stripped with different concentration of  $H_2SO_4$  at O/A: 1/1, for 15 min to get the pure solution of Cu and Ni, respectively. Result (Figure 3) indicates that stripping of Cu was increases from 44% to 99% with increase in acidic concentration of  $H_2SO_4$  in the range of 2-10%. The stripping of Ni was observed 38% in 2%  $H_2SO_4$  solution and it increases on increasing the acidity of stripping agent. The complete stripping was found in 10%  $H_2SO_4$  solution. Finally, a process flow sheet is developed for recovery of copper and nickel from PCBs of personal computer is presented in Figure 4.

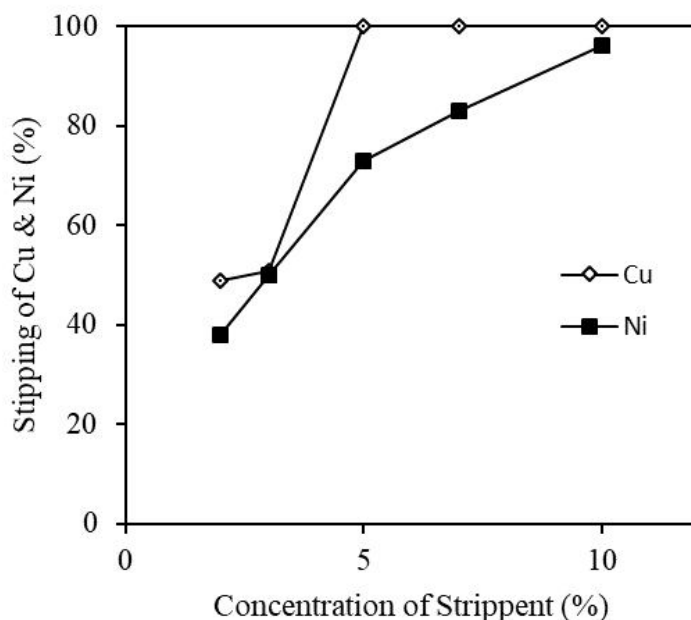


Figure 3. Effect of Strippent concentration on Cu & Ni stripping

[Strippent: Different concentration of  $H_2SO_4$ ; O/A ratio: 1:1; Time: 15 min]

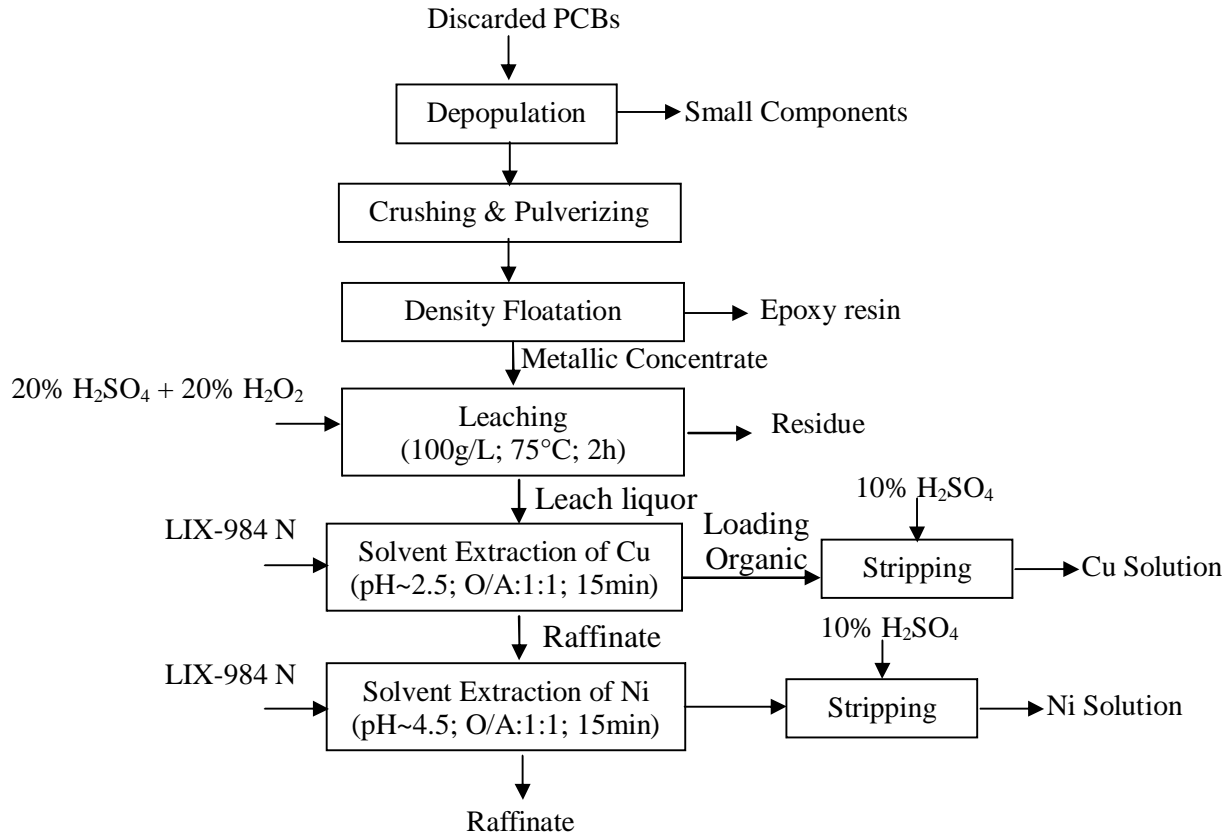


Figure 4. Generalized flow-sheet for the recovery of Cu and Ni from PCBs of Personal computers.

#### 4. CONCLUSIONS

Based on the lab-scale studies, the following conclusions have been made as given below.

- ❖ More than 95% metallic concentrate of copper, 1% Nickel were achieved from discarded PCBs of personal computer by crushing, grinding and gravity process.
- ❖ It was found that 99% Cu and Ni leached in 20% H<sub>2</sub>SO<sub>4</sub>, 20% H<sub>2</sub>O<sub>2</sub>, 2h, 100 g/L, and rpm- 450 at 75 °C.
- ❖ Further, Cu and Ni were extracted from leach liquor using extractant LIX 984 N by solvent extraction technique. Almost 99% Cu and Ni were extracted at O/A ratio: 1:1 in 15 min at pH 2.5 and 4.5, respectively.

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