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Bioleaching for Metal Recovery from Telecoms Switchboard

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Abstract

Printed circuit boards (PCBs) are a necessity for electronic equipment to function especially in the telecommunication industries. From a PCB for broadcasting networks to PCBs for office communications they are what makes electronic communications equipment operate. The sophistication possible with modern electronic and microelectronic devices depends ultimately on the materials they are made from. Metals have assumed a vital role in electronics at every stage in their evolution. PCBs are rich in base and precious metals, and should be considered as secondary resources. Bioleaching is a proven green and sustainable method for metal recovery as demonstrated in the mining industry, but application to recover metals from electronic equipment is still limited. In this study, bioleaching is applied for the first time to the telecommunications products that have reached the end of their useful life. Because several biological and physicochemical parameters can influence bioleaching, the first step in this study was to analyse the metal content of PCBs. In the second part, the effect of different parameters on bioleaching is investigated, with the aim of improving metal recovery. Altogether, the study aims to demonstrate the effectiveness of bioleaching for metal recovery from WEEE.

Keywords: PCBs, Bioleaching, PCBs, Metal recovery

1. Introduction

Accumulation of large quantities of electronic waste on earth presents both threat and opportunity due to the nature and large metal content of these solid wastes. Electronic waste is produced both in household and urban applications, including the telecommunication industry. Due to the rapid advance in networking and telecommunication technologies, there is an urgent need for the management of discarded facilities of dated systems (Roy, 2016). These facilities contains tons of switch boards which are rich in different metals including base, precious and rare earth metals. This necessitates the metal recovery from PCBs of broadcasting networks for both environmental and economic incentives.

The conventional technologies for metal recovery from electronic waste include pyrometallurgy and hydrometallurgy, which are considered environmentally challenging by environmental agencies. Bioleaching technology despite its low technology readiness level, is a green and sustainable method with lower capital and operational cost and less negative environmental impact (Isildar, 2018). This method takes advantage of intrinsic ability of the microorganisms to produce metabolites and lixiviant that solubilise metals from their solid states (Pham and Ting, 2009). The present work is an investigation of the growth and activity of *Acidithiobacillus ferrooxidans*, one of the most widely used microorganisms for bioleaching.s.

2. Material and Methods

The metal content of the boards was analysed by Inductively-coupled plasma optical emission spectrometer (ICP-OES; Perkin Elmer Optima 8300, Singapore); samples were digested on a hot plate for 24 hours with reverse aqua regia. ICP –OES was also used for the analysis of the leachate and measurement of the recovered metals.

The bacteria (A. ferrooxidans) used in the work were obtained from Bangor University, Bangor, Wales. Bacteria were cultivated in a 9K medium with pH adjusted to 2 using 1%. After 4 days, when the culture reached its maximum growth and the medium turned to red due to the conversion of Fe^{2+} to Fe^{3+}, 0.1%w/v shredded PCB was added to the medium. Since electronic waste sample was added to the medium following the established growth of the bacteria, this method can be considered as a 2-step bioleaching method (Heydaraian et al. 2018). Daily measurement of pH and concentration of Fe^{3+} ions were performed as they are indicators of bacterial growth and activity. These parameters were measured daily for 7 days.

Ferric ion concentration was measured based on the 5-sulfosalicylic acid dehydrate methods (Karamanev et al., 2002).

3. Results And Discussion

3.1. PCB metal content

Metal content analysis of the boards indicated the presence of rare earth, base and precious metals in the board (Table 1.) The results showed that almost 26.5% of the analyzed metals were base metal with copper containing 19.4% of the PCBs. There is a necessity to remove the base metal in the first stage of the work, so that the precious metal recovery can be done with improved efficiencies in further steps (Natarajan and Ting 2014).

Table 1. Switch board metal content mg/gr; base (blue), precious (yellow) and rare earth (green) metals.

Al	**Cr**	**Ga**	**Fe**	**Pb**	**Mn**
33.89	0.02	0.05	8.23	17.84	2.27
Mg	**Ni**	**Si**	**Ag**	**Zn**	**Cu**
1.20	3.52	0.02	0.08	3.67	194.37
Au	**Pd**	**Pt**	**Er**		**Nd**
0.17	0.05	0.01	0.47		0.11

3.2. Bacterial activity

The concentration of ferric ions and pH of the medium was measured and can be seen in Figure 1. The constant pH drop is due to the chelating action of extracellular polymeric substances ($Fe^{3+} + 3EPS - H \rightarrow Fe(EPS)_3 + 3H^+$)as well as the production of H^+ ions due to jarosite formation ($Fe(OH)_3 + SO_4^{2-} + Fe^{3+} + H_2O + K^+ \rightarrow KFe_3(SO_4)(OH)_6 + H^+$) (Nie et al. 2014). Similar pH trend has been observed in the work of Heydarian et al. (2018) after addition of lithium ion batteries to acidophilic bacteria. The presence of H^+ ions enhances the proton attack for solubilisation of target metals.

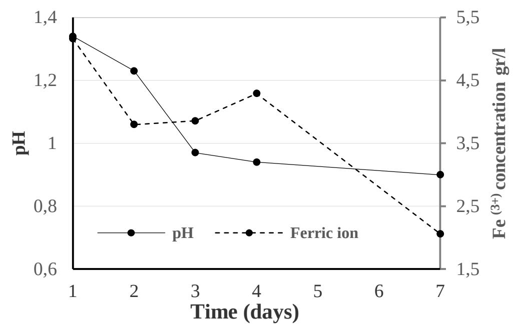

Figure 1. Metabolite characterisation

Ferric ion concentration in the solution decreased after addition of the electronic waste as the metal recovery is due to the electron exchange between Fe^{3+} ions and zerovalent metals available in PCB ($Fe^{3+} + Cu \rightarrow Fe^{2+} + Cu^{2+}$). Bacteria have the ability to convert back Fe^{2+} to Fe^{3+}. It can be observed that after several days Fe^{3+} concentration decreases more significantly as bacteria lose their ability to convert ferric back to ferrous during their dead phase.

3.3. Metal recovery

The results showed that after 7 days of bioleaching, 34.4% Cu, 4.0% Zn, 9.6% Mn and 6.2% (Figure 2) were recovered. The metal recovery process takes place through redoxolysis and acidolysis mechanism (Xin et al. 2016). As the bacteria improves the acidity and converts ferrous ions to ferric, they enhance metal solubilisation from PCBs by both mechanisms. These results are encouraging initial results that pave the way toward more efficient metal recovery, including gold and other precious metals in further steps of the research.

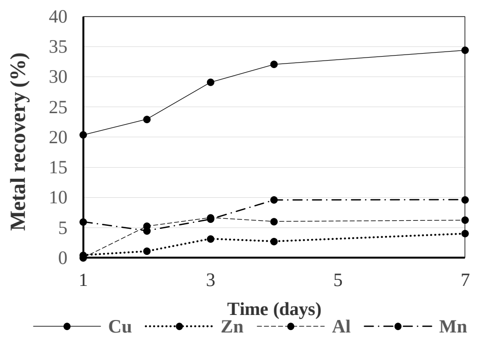

Figure 2. Metal recovery from PCBs

4. Conclusion

In this work, a two-step bioleaching process was performed using *A. ferrooxidans* for base metal recovery. Bacterial growth and activity were investigated with an initial recovery of 34.4% Cu, 4.0% Zn, 9.6% Mn and 6.2% obtained after 7 days.

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