Biorecovery of Metals from Electronic Waste

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INTRODUCTION

Electronic waste, or e-waste, is being generated two to three times faster than other waste streams (Grossman, 2006; U.S. EPA, 2008). E-waste is presently reused, remanufactured, recycled, incinerated or disposed of in landfills (Ilyas *et al*., 2007; Cui and Zhang, 2008). The U.S. Environmental Protection Agency (EPA) estimates that 500 million computers were discarded between 2000 and 2007, 2 million tons of tech trash ended up in landfills, and only 400 thousand tons were recycled (U.S. EPA, 2008). Estimates by the Natural Resources Defense Council indicate that 130 thousand computers are discarded daily and that one million cell phones were discarded in 2006 (NRDC, 2008).

Current treatments of e-waste include pyrometallurgical and hydrometallurgical methods, processes that are energy intensive. Recently some studies with microorganisms have been conducted to explore biotreatment of e-waste (Brandl *et al*., 2001; Choi *et al*., 2004; Faramarzi *et al*., 2004; Ilyas *et al*., 2007; Cui and Zhang, 2008), with the expectation that they may lead to the development of more efficient and less costly processes.

In this study we have investigated the bioleaching of metals (Cu, Ni and Zn) from computer printed circuit boards using *Acidiphilium acidophilum*. Bioleaching is the extraction or mobilization of metals from materials by microorganisms. Printed circuit boards (PCBs) are the essential components of most electronic waste, and some metals in PCBs are potentially toxic; when not disposed of properly these metals can leach into soil and water and seep into watersheds (Grossman, 2006). *A. acidophilum* is a mesophilic, acidophilic, heterotrophic bacterium that bioleaches metals (Rohwerder *et al*., 2003).

MATERIALS AND METHODS

Electronic Waste (PCBs)

Coarsely shredded PCBs were obtained from a local recycling company. Samples were shredded and meshed out in the lab to a final particle size of 0.8 to 1.7 mm. Average metal content of the samples was determined by inductively coupled-plasma mass spectrometry (ICP-MS).

Bacterial Strain and Growth Conditions

Acidiphilium acidophilum (ATCC 27807) was grown at 26ºC and 150 rpm in 9-K glucose medium.

Experimental Procedure

Bioleaching experiments were conducted under sterile conditions in 250-mL Erlenmeyer flasks containing 100 mL of a bacterial/PCB suspension; the flasks were incubated on an orbital shaker at 26ºC and 150 rpm. The initial bacterial density and pH were $3x10^7$ cells/mL and 3.5, respectively. A wide range of PCB amounts was tested and narrowed down to PCB final concentrations varying between 8 and 32 g/L. Throughout the experiments pH and cell density were measured; at the end of the experiments the amounts of Cu, Zn and Ni released into the culture medium (i.e. bioleached) were determined by ICP-MS. Controls consisted of inoculated flasks without PCBs and of non-inoculated medium with PCBs. Experiments were stopped at the onset of the cell death phase.

RESULTS AND CONCLUSIONS

Table 1 shows the percentages of Cu, Ni and Zn bioleached from PCB suspensions at concentrations of 8 and 16 g/L, in the absence or presence of *A. acidophilum*.

Table 1: Percentage of Bioleached Metal

	8 g/L PCB		16 g/L PCB	
Metal	**Without bacteria**	**With bacteria**	**Without bacteria**	**With bacteria**
Cu	0.9	9.1	0.2	3.6
Ni	78.8	80.8	85.9	86.0
Zn	10.6	30.6	6.4	40.8

Results indicate that the mesophilic bacterium *A. acidophilum* bioleaches Cu and Zn from shredded PCBs, and that it may not bioleach Ni (results are

inconclusive). Low pH and PCB concentrations lower than 20 g/L are favorable to bacterial growth and metal bioleaching (results for higher PCB concentrations are not shown here); these results are consistent with other studies (Brandl *et al*., 2001; Ilyas *et al*., 2007).

REFERENCES

Brandl, H., Bosshard, R., and Wegmann, M. (2001). "Computer-munching microbes: metal leaching from electronic scrap by bacteria and fungi". *Hydrometallurgy*, Vol. 59, pp 319-326.

Choi, M., Cho, K., Kim, D., and Kim, D. (2004) "Microbial recovery of copper from printed circuit boards of waste computer by *Acidithiobacillus ferrooxidans*". *Journal of Environmental Science and Health, Part A - Toxic/Hazardous Substances and Environmental Engineering*, Vol. 39, pp 2973-2982.

Cui, J., and Zhang, L. (2008). "Metallurgical recovery of metals from electronic waste: A review". *Journal of Hazardous Materials*, Vol. 158, pp 228-256.

Ilyas, S., Munir, A.A., Niazi, S.B., and Ghauri, M.A. (2007). "Bioleaching of metals from electronic scrap by moderately thermophilic acidophilic bacteria". *Hydrometallurgy*, Vol. 88, pp 180-188.

Faramarzi, M.A., Stagars, M., Pensini, E., Krebs, W., and Brandl, H. (2004). "Metal solubilization from metal-containing solid materials by cyanogenic *Chromobacterium violaceum"*. *Journal of Biotechnology*, Vol. 113, pp 321-326.

Grossman, E. (2006). *High Tech Trash – Digital Devices, Hidden Toxics and Human Health*, Island Press, USA.

Natural Resources Defense Council (2008). What to Do About E-Waste. http://www.nrdc.org. 11/14/08.

Rohwerder, T., Gehrke, T., Kinzler, K., and Sand, W. (2003) "Bioleaching review part A: Progress in bioleaching: fundamentals and mechanisms of bacterial metal sulfide oxidation". *Applied Microbiology and Biotechnology*, Vol. 63, pp 239-248.

U.S. Environmental Protection Agency (2008). Electronic Waste and eCycling. Available at http://www.epa.gov/region1/solidwaste/electronic/index.html. 11/14/08.