RECOVERY OF METALS FROM ELECTRONIC SCRAP (E-WASTE) BY HALOTOLERENT THIOBACILLUS CUPRINUS N-57

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ABSTRACT

Bioleaching is a Conversion of solid metal values into their water soluble forms using microorganisms. It is a method of extraction of metals from solid matrix. It is a hydrometallurgical process where mobilization of metal takes place from solid phase to liquid through microbial activity. Electronic waste (E-waste) is also known as WEEE (Waste Electric and electronic Equipment).

By considering this, In the present study halotolerant Thiobacillus cuprinus N-57 is explored for bioleaching of metals from e-waste. Thiobacillus cuprinus N-57 isolated from hyper saline soils of Kolhapur district of Maharashtra, India on 9 K medium. It was identified using Bergey’s manual of systematic bacteriology. Bioleaching study was carried out in both shake flask as well as bioreactor.

Results showed that in the shake flask Thiobacillus cuprinus N-57 tolerates 40 g/L of e-scrap waste when supplemented with 0.5 g/L of Yeast extract. At 120 rpm and 40 °C temperature, about 75% of copper and 72% Zinc can be extracted after 12 days by shake flask method and 80%of Copper and 74% Zinc can be extracted by bioreactor study in 10 days.

Present study indicated the usefulness of Thiobacillus cuprinus N-57 in bioleaching of metals from electronic scrap waste and can be used as a potential candidate for bioleaching as a pollution free process. The consortium prepared by the present way can be used for metal solublization rather than using purified organism or defined consortium. More importantly the consortium used in the present study would be competitive in the non sterile conditions of commercial bioleaching process. From the present studies it is concluded that the bioleaching could be a good option for extracting metals from waste printed circuit boards.

INTRODUCTION

E-waste is defined as any equipment that is dependent on electric currents or electromagnetic fields in order to work properly including equipment for the generation, transfer and measurement of current Schafer et al.,(2003). It is the waste generated during the manufacture of electric hardware, and discarding of used electronic products such as end-of-life computers, printed circuit boards and connectors Sum (1991). Electronic scrap contains multicomponent mixtures about 30 % polymers, 30% refractory oxides and 40 % metals. The
metals in electronic scrap are comprised of base metals and precious metals. The metals which account for 39% of the scrap, including Copper (20%), Iron (8%), Nickel (2%), Tin (4%), Lead (2%), Aluminium (2%), and Zinc (1%). The precious metals include Gold (0.1%), Silver (0.2%) and Palladium (0.005%). Most of these metals are classified as heavy metals with density greater than five Gadd (1992).

Rapid development in computer and electronic technologies has resulted in the increasing rate of manufacture of electronic devices. According to Zhang and Forssberg, (1999) the consumption of electric and electronic equipment in Europe has been increased to seven million tons. It is expected 3% annual increase. In United State a total 4% of Electronic market has been emerged, increasing manufacture of electronic goods and relative short life of electric and electronic devices has resulted in increased production of electronic waste. The generation of such huge amount of scrap electronics presents a difficult task for the various countries including islands due to scarcity of landfills sites available as well as due to metal toxicity.

Computer equipments has the fastest growing portion of electronic waste because of rapid changes in computer technology and electronic data management and communications. Generally, computer equipment has life of 3 to 20 years before it is scrapped Malhotra (1985). Currently the useful life of a computer is only 3-5 years and is shrinking. It is projected that more than 63 million personal computer will be retired in 2012 in United States as per the National Safety Council (2002).

Electronic scrap waste contains both kind of metals, valuable as well as toxic heavy metals. Day by day huge quantities of electronic waste is generated in significant quantity, therefore there is a need to search for a better and ecofriendly method for its disposal as detoxification of heavy metals using recovery methods.

The response by various countries including Euopean Union, United States and Japan to implement legislations and directives to reduce the disposal and promote the recycling of e-waste constitutes a significant step in addressing this important issue Victoria (2002). This legislation, will not be sufficient to solve this problem unless some technological solutions or sustainable cost effective and ecologically sensitive, recycling processes are developed.

In view of this, E-waste is mainly disposed by incineration, land filling, however, it has created a toxic time bombs that threaten the ecosystem and animal health Victoria (2005). In view of this, recycling is a mere necessity to the problem of electronic waste today and future.

In bioleaching process the interaction between metals and microorganisms takes place this allows metal recycling by a similar process as that of natural biogeochemical cycles and is therefore ecofriendly, with low cost and low energy requirement.

By considering this, In the present study halotolerent Thiobacillus cuprinus N-57 is explored for bioleaching of metals from e-waste using Thiobacillus cuprinus N-57 isolated from hyper saline soils of Kolhapur district of Maharashtra, India.

**MATERIALS AND METHODS**

**Source of electronic scrap**

Electronic scrap in the form of printed circuit boards was procured from an electronic scrap shop in Kolhapur city of Maharashtra, India. For experiment the scrap was crushed and ground to fine powder of 100 to 150 um particle size by using ring mill grinder and initial metal percentage was determined by atomic absorption spectrometry as per Greenburg et al., (1992).

**Chemical analysis**

For metal analysis the electronic scrap 1 gm was dissolved in 100 ml of triple distilled water. The concentration of dissolved metal ions was determined by Atomic absorption spectrophotometer.

**Microorganism for Bioleaching of electronic scrap**

*Thiobacillus cuprinus* N-57 was isolated from hyper saline soil of Kolhapur district of Maharashtra, India on modified 9 K medium as per Silvermann, and Lundgren (1959). In brief composition (g/L), Solution-A: (NH₄)₂SO₄(3.0), KCl(0.1), K₂HPO₄ (0.5), MgSO₄.7H₂O(0.5), Ca(NO₃)₂ (10mg/L), 10N H₂SO₄(1ml) Distilled water(700ml). Solution-B electronic waste powder (40g), distilled water (300ml). It was identified by using morphological, cultural, biochemical, methods as per Bergey’s manual of systematic bacteriology by Williams et al., (1989) and as per MICRO-IS software Portyrrata and Kricheovsky(1992).

**Bioleaching procedure**

A standard test procedure was followed ASTM (1990). Briefly, 1.0 g of e-scrap powder was added to 100 ml of 9 K medium in 250 ml conical flasks. Medium was sterilized at 110°C for 10 minutes and was inoculated with 0.1 ml of actively growing culture of *Thiobacillus cuprinus* N-57 at initial cell density of 1.0 *10⁷ cells/ ml. Cell density was determined by Petroff-Hauser bacteria counter and as per Nephelometer standards.

**Process optimization:** Unless otherwise stated the experiments were carried out in 250 ml of flasks with 100 ml of modified 9 K medium. During incubation liquid samples were removed periodically filtered, centrifuged and total Cu²⁺, Zn²⁺ concentration was determined by Atomic absorption spectrophotometer.

Bioleaching study was carried out in both shake flasks as well as in bioreactor.

**Shake flask study**

Optimization of temperature: For optimization of temperature inoculated flasks were incubated at temperatures 20°C, 30°C, 40°C, 50°C, 60°C. For pH, at pH1.5, 2.5, 3.5, 4.5, 5.5. For Agitation at 40 rpm, 60 rpm, 80 rpm, 100 rpm, 120 rpm, 140 rpm, 160 rpm, 180 rpm, 200 rpm and 220 rpm. For yeast extract with 0.5 g/L,1.0 g/L, 1.5 g/L, 2.0g/L, 2.5 g/ L,3.0g/L, 3.5 g/L, 4.0g/L, 4.5 g/L, 5.0g/L, and 5.5 g/L. For optimization of inoculum, culture was added from 1%, 2%, 3%,4% up to 10% v/v with a cell density of 1.0 * 10⁷ cells/ ml. For pulp density flasks with 9 K medium containing e-scrap powder
RESULTS AND DISCUSSIONS

Table 1 indicates Primary analysis of e-scrap powder. This indicated the 38.2% copper as per table-1.

<table>
<thead>
<tr>
<th>Elemental/Mineral</th>
<th>Composition %</th>
</tr>
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<tbody>
<tr>
<td>Cu^{2+}</td>
<td>20.2</td>
</tr>
<tr>
<td>Zn^{2+}</td>
<td>12.4</td>
</tr>
<tr>
<td>Fe^{2+}</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Process optimization with respect to shake flask study indicated that the maximum bioleaching observed at Temperature 40°C, pH (4.5), Agitation (120rpm), Aeration (38%), and Yeast extract (0.5g/L) were kept optimum. During batch run 2 ml quantity of medium was collected after every 24 hours and analyzed for growth pattern and concentrations of copper and zinc.

Bioreactor study: For standardization of growth and bioleaching process by Thiobacillus cuprinus N-57. The parameters which were optimized on shake flask study were determined with fully automatic microprocessor controlled bioreactor model (Biostat B,B Brown international Germany) with 5L capacity.

All parameters viz, Temperature, pH, Agitation, Aeration, were monitored with fully automatic device. Different parameters i.e. Inoculum size, (4% v/v), Temperature (40°C), pH (4.5), Agitation (120rpm), Aeration (38%), and Yeast extract (0.5g/L) were kept optimum. During batch run 2 ml quantity of medium was collected after every 24 hours and analyzed for growth pattern and concentrations of copper and zinc.

Table-2 and Fig-1 indicates the course of metal extraction during bioleaching process by Shake flask.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu^{2+}</td>
<td>22.2</td>
</tr>
<tr>
<td>Zn^{2+}</td>
<td>12.4</td>
</tr>
<tr>
<td>Fe^{2+}</td>
<td>9.1</td>
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</table>

From Table 2, it was observed that Thiobacillus cuprinus N-57 oxidize iron optimally at pH between 3 to 3.6. My results indicated optimum leaching at pH 4.0 which are similar to that of Silvermann and Lundgren (1959). Effect of temperature on bioleaching indicated that optimum leaching by uncharacterised strain at 37°C Ahonen and Tuovinen (1995). My strain gives optimum leaching at 40°C. Wang et al., (2008) studied the effect of inoculum on metal dissolution. It was observed that maximum recovery at 3 % of inoculums size. My result indicated maximum recovery at 4% inoculums size.

Brand et al.,(2001) studied the bioleaching of metals from electronic scrap their results indicated that the metals can be

Shake flask study showed that there was an initial lag of 24 hours and a significant e-scrap powder leaching started after 2nd day and continued up to 12th day. The rate then decreased as iron was consumed. After 22nd day a total copper extraction of 75% and Zinc 72 % was achieved by shake flask. Table-3 and Fig-2 indicates course of bioleaching during bioreactor study. Results indicated that There was a lag of 24 hours as that of shake flask study, the effective leaching started after 2nd day of bioleaching and continued up to 10th day of leaching process. The rate then decreased as iron was utilized. Effect of pH was studied by Silvermann and Lundgren (1959). It was observed that Thiobacillus cuprinus N-57 oxidize iron optimally. Figure 1 and 2 indicated the course of metal extraction during bioleaching process by Shake flask and Bioreactor.

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Figure 1 and 2 indicated the course of metal extraction during bioleaching process by Shake flask and Bioreactor.

Table 3 Chemical analysis of e-scrap powder during bioleaching (Bioreactor study)

<table>
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recovered from electronic scrap after 18 days using *Sulfobacillus thermosulfidooxidans* my results indicated that heavy metals from electronic scrap can be recovered within 10 to 12 days of bioleaching experiment. Brown (2009) studied the effect of pH on bioleaching of metal from electronic scrap, he observed maximum bioleaching at pH 4.5 however, my results also showed maximum bioleaching at pH 4. Some what similar to Brown. Ilyas *et al.* (2007) found the highest metal bioleaching from electronic scrap at 10% concentration. My results showed maximum leaching at 4%. Gadd and Griffiths (1978) and Mizutani *et al.* (1996) observed the effect of pulp density on metal leaching with fungal culture. He observed maximum leaching at 2% while my results showed maximum leaching at 4% this also indicates bacteria are more resistant to electronic scrap pulp as compared to fungi. Ahonen and Tuovinen (1989) studied the effect of temperature on bioleaching of metals they observed optimum leaching in between 28 °C to 30 °C, my results indicated maximum leaching at 40 °C.

Waksman and Joffe (1922, Kanishi and Sataru (1992) isolated bacteria from soil environments and found that the bacteria from soil environments are also equally competent in leaching process. As my culture is isolated from a saline soil environment, also has a very good leaching ability. In literature no reports have been found on bioleaching of electronic scrap by halotolerent *Thiobacillus cuprinus* N-57, My report may be the opening of new era for use of halotolerent *Thiobacillus cuprinus* N-57 as a potential candidate for bioleaching of metals from electronic scrap.

**CONCLUSIONS**

Optimum bioleaching of metals from electronic scrap by *Thiobacillus cuprinus* N-57 was observed at pH 4.0, Temperature 40°C, Agitation 120rpm, pulp density 4%, Yeast extract 0.5g/L.

The results from these studies showed that metals can be recovered from electronic scrap by microbial leaching using *Thiobacillus cuprinus* N-57.

Process may be advantageous over conventional method of metal extraction. This promises to be a potential technique for bio remediation of electronic scrap material.

Present study reports the use of halotolerent *Thiobacillus cuprinus* N-57 as a bioleaching strain.

**Acknowledgements**

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**References**
