Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 3; January-March, 2015, pp. 224-226

http://www.krishisanskriti.org/jbaer.html

Management of Hazardous Glass Waste by Greener Techniques

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Abstract—*Metal containing glasses, like fluorescent and colored glasses nowadays are used for various applications both in household and electronic equipments. Majority of metals present in these glasses are heavy metals thus making the resultant waste in the category of hazardous waste. Aforesaid waste poses a serious threat to both humans and environment. Therefore the management of such type of waste is a serious problem. The existing recycling techniques include (i) Mechanical recycling (remelting and shaping) (ii) as material resource, to make concrete admixture, masonry blocks, ceramic tiles, flux in metallurgical processes, foam glass and for decorative purposes; and (iii) land filling, which have its own limitations. The current research proposes a new green technique for its recycling as material resource followed by removal/recovery of heavy metal. A hybrid leaching technique by incorporating compatible microbe and chemical is proposed for heavy metal recovery from the glasses. Microbial incorporation can make the technique comparatively eco-friendly, and hence proposed here as green.*

Keywords: *CRT glass, CFL glass, heavy metal, hybrid technique*

1. INTRODUCTION

Colored glass products are continuously in demand for household, industrial purpose and for electronic equipments which in result generates huge waste. These glasses are composed of various metals. The majority of metals present in the colored glasses are heavy metals which are added to the glass matrix during its formation for imparting color and for specific functions for example colored glasses like fluorescent, CRT glasses etc. The resultant glass waste management is complicated because of its hazardous nature. This waste gives a serious threat both to humans and environment.

The existing recycling techniques for the management of glass waste are (*i*) Mechanical recycling (remelting and shaping) (*ii*) as material resource for making masonry blocks [1], concrete admixture [2], ceramic tiles [3], flux in metallurgical processes [4], foam glass [5] and for decorative purposes [6]; and (*iii*) land filling, which have its own limitations.

The aim of this article is to discuss a new green hybrid technique for the management of hazardous glass waste especially CFL (Compact Fluorescent Lamp) and CRT (Cathode Ray Tubes) glass. The hybrid leaching technique by incorporation of both chemical and microbe together make the efficient metal recovery from the waste glass.

2. HAZARDOUS GLASS WASTE: CFL AND CRT

The glass of fluorescent lamps from inside is coated with phosphor powder containing mercury vapor. Mercury is added to the lamp in the form of solid, liquid or amalgam [7]. Some manufacturers use liquid mercury which is less expensive, while other use mercury in the form of amalgam. Elemental mercury (Hg^0) during lamp operation is oxidized and adsorbed onto the glass, phosphor powder and to the metal component of the lamp [8] thus making these parts polluted. The mercury added to the fluorescent lamps is in very small quantity in milligrams and varies according to lamp type, wattage, brand and manufacturing plant. Mercury is a well known highly toxic heavy metal and its toxicity depends on the chemical form and route of exposure. It is hazardous to both infants as well as adults.

Lead (in the form of PbO) is widely used in CRT glass due to its specific property. It protects harmful exposure of X- rays generated from electron gun [9]. Lead content in CRT monitor varies from black and white towards colored, older towards newer, according to size etc. With respect to total oxides black and white CRT consists of 2.8-4.4% and color funnel consists of 19-23% PbO [10]. The toxic effects of lead include: anaemia, kidney damage, hypertension, cardiac disease, immune system suppression (antibody inhibition) neurological damage and can also cause skin damage, headache, nausea, gastric and duodenal ulcers.

3. MANAGEMENT OF HAZARDOUS GLASS WASTE

Chemical and biological remediation of heavy metals have their own limitations as by biological leaching (involving

microbes) complete recovery of metal alone is not possible and chemical leaching on the other hand have environmental consequences [11]. To overcome this problem associated with chemical and biological remediation methods, hybrid methodology have been proposed here which involves combination of safer chemicals and biological leaching for an efficient method for metal extraction from glass waste.

The possible combinations of hybrid technique for mercury removal are as follows:

1. Chemical leaching (HCl and $FeCl_3$) and volatilization of mercury by bacteria [12].
2. Addition of 1 mM KI to mercury-contaminated soil increased the mercury concentration in Willow plant by a factor of 5, 3, and 8 times in the leaves, branches, and roots, respectively [13].
3. Chemicals as sodiumthiosulfate, ammoniumthiocyanate, potassium iodide, EDTA, NTA, dimercaptosuccinic acid, mercaptopropionic acid, mercaptoethanol, thiourea, thiocyanate and hydrogen peroxide, ammonium thiosulfate, and urease for chelating mercury have been used widely to enhance the plant uptake of mercury [14]. These chemicals increase the solubility of mercury and enhance the plant uptake of mercury from the soil.

Hybrid combination for Pb removal is chemical reagents either used with microbes or plants. The possible combinations of hybrid technique for lead removal are as follows:

1. Chemical reagent + microbe

Chemical and microbial combinations involving the use of EDTA with either Acidithiobacillus ferrooxidans or bacterial strain DSM 9103 are mentioned in literature [15].

Many fungi (A. niger, P. bilaiae, and other Penicillium sp.) secrets various organic acids like citric, tartaric, and oxalic acids which can act as chelating agents hence employed for the extraction of Pb [16].

Oxalate along with ammonium citrate can be used for the extraction of Pb, the efficiency of this process is reasonably enhanced by adding A. niger or Penicillium species [16].

1. Chemical reagent + plant

In order to enhance the availability of Pb in soil and translocation from root to shoot, chelating agents are applied in small doses such as EDTA, DTPA, NTA, CDTA, EDDS, and citric acid. EDTA being the most efficient chelator for Pb is used widely to solubilize Pb in the soil [17]. There was a twofold increase in the accumulation of Pb by applying EDTA with acetic acid in Indian mustard shoots as compared with the application of EDTA alone [18].

4. CONCLUSION

Hybrid techniques are found to be most promising both in terms of efficiency and environmental issues. This methodology has the potential to overcome the problems associated with both chemical and biological extraction techniques individually for the metal present in hazardous glass waste. The advantages of the hybrid methodology are:

1. Efficient metal removal from waste glasses.
2. Less time consuming then biological leaching alone.
3. By using certain specific ligands and microbes it is possible to achieve metal specific extraction.
4. Metals present in trace quantity in their ore, can be extracted by this technique.

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