Supplementary Material

Biosorption and Bioleaching of Heavy Metals from Electronic Waste Varied with Microbial Genera

Table S1. Advantages and Disadvantages of conventional and biological methods for efficient metal recovery from e-waste.

Conventional methods	Advantages	Disadvantages	References
Chemical precipitation	• Integrated physico-chemical process, • low capital cost, • simple in operation, • adaptive to high pollutant loads, • efficient for removal of metals and fluorides	• Inefficient for metals present in less amount, • pH dependent • requires chemicals such as lime, oxidants and hydrogen sulfide, • oxidation required if metals are complexed, • maximum sludge generation during the entire process • requires extra cost for sludge management	[5,6]
Coagulation/Flocculation	• Integrated physico-chemical technique, • simple process, • low capital cost, • efficient for removal of soluble, insoluble metals and colloidal particles	• pH dependent • requires non-reusable chemicals, • maximum sludge generation • requires extra cost for sludge management • not efficient for As removal	[7,8]
Ion exchange	• Technologically simple process, • rapid, • efficient process for removal of valuable metals up to ppb levels, • can be integrated with other processes (precipitation and filtration)	• High operational cost (maintenance and initial cost of the resin), • not efficient for dispersal dyes and drugs, • large volume requires large columns, • rapid saturation and clogging of the reactor, • easily contaminated with organic matter, oils • requires physico-chemical pretreatment	[9]
Filtration	• Simple process, • smaller space requirement, • high separation selectivity with fast kinetics, • efficient for removal of wide range of pollutants	• High operational cost due to reactor clogging, • require several types of adsorbents, • regeneration is quite costly and results in loss of material,	[6]

		• not efficient for certain metals and dye stuffs	
Electro-dialysis	• Simpleprocess, • efficient even at high concentration, • no chemicals required, • efficient for removal of dyes, salts, minerals and dissolved inorganic matter with high separation selectivity	• High maintenance cost • high energy requirement, • specific process, • rapid clogging of membrane, • limited flow rates • low throughput	[10]
Photo-catalysis	• Simple, • highly efficient process for removal of organic pollutants and metals simultaneously, • production of energy	• Initial investment costs, • formation of dioxins and other pollutants, • high operational and maintenance cost, • limited applications	[11]
Biological methods	• Low cost, • high efficiency, • potential metal recovery, • regeneration of biosorbent, • economically attractive, • non-requirement of additional nutrient, • utilization of large number of microbial species either in pure or mixed cultures, • environment-friendly, • minimization of sludge	• Possibility of biotransformation or biodegradation, • slow process, complexity of microbiological mechanisms, • necessary to maintain optimized conditions, • possible sludge bulking and foaming	[12–14]

Table S2. Research studies emphasizing the potential of biological remediation of the E-waste.

Physico chemical practices	Biological practices	Remarks
• Hydrometallargy: Gold mining involves use of leach reagent i.e. cyanide • Exhibits high gold recovery • Robust and low cost • environmental damage • mismanagement produces noxious side products which tempers recycling process	• No leaching agents are required • Microorganisms themselves act as leaching agents • Environment-prudent	[25]
• Cu, Pb and Sn recovery from scrap printed circuit boards (PCBs) by combination of leaching, electrochemical ion exchange and electrodeposition • Use of aq. HNO_3 stripping solution for Cu and Pb extraction • Sn precipitation as $2SnO_3$ at high acid concentrations (>4 M dm^{-3})	• No huge capital investment is required	[26]

• Poor current efficiency due to cathodic Pb deposition • Requirement of huge capital investment • Physical processes require low capital • suffer from huge metal loss (10-35%) • brominated flame retardant dust problem	• No Brominated flame retardant dust problem was observed		[27]