WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 5.045
Volume 3, Issue 10, 753-760. Research Article ISSN 2277 – 7105

BIODEGRADATION OF ELECTRONIC WASTE USING BACTERIA

Subhashree Bhuyan, Jyotirmayee Kodukula, Swarnkumar B, Astha Sinha and Osborne W. J*,

Microbial Bioremediation Lab, School of Bioscience and Technology, VIT University Vellore- 632014, India.

Article Received on
17 Sept. 2014,

Revised on 11 Oct. 2014,
Accepted on 06 Nov. 2014

***Correspondence for Author**
Osborne W. J
Microbial Bioremediation Lab, School of Bioscience and Technology, VIT University Vellore- 632014, India.

ABSTRACT

The dumping of e-waste like unused electronic gadgets, motherboards etc into the environmental reservoir cause many detrimental effects on the flora and fauna. The present study was carried out to determine the ability of bacteria isolate from waste dumping sites in the biodegradation of electronic waste. Enrichment was performed and 10^{-5} and 10^{-6} was plated onto nutrient agar plates supplemented with 0.1g of e-waste. Effective isolate VITJS1 and VITJS2 was biochemically characterized and the isolates were found to be gram positive rods. Further the ability of the effective isolate to degrade various heavy metals found in e-waste was assessed separately using techniques like AAS. The culture was found to solubilize zinc metal powder effectively.

KEYWORDS: e-waste, biodegradation, solubilization, AAS, Enrichment.

INTRODUCTION

Electronic waste also termed as waste of electric-electronic equipments (WEEE) is the fastest growing waste stream in municipal wastes with an annual growth rate of about 3-5 %. These e-wastes are considered as a high degree pollutants and are toxic to the environment. [1] Electrical and electronic equipments are composed of hazardous materials that are harmful to human health and environment if not disposed carefully. Some of the naturally existing elements though not harmful in the natural state but their use in manufacture of electronic equipments often result in compounds which are hazardous (e.g. chromium becomes chromium IV). [2] The following is the list of the mostly commonly found toxic substances present in e-waste.

Arsenic: Arsenic is a poisonous metallic element. Chronic exposure to arsenic may lead to various skin disorders and decrease nerve conduction velocity, lung cancer and can befatal. [3]

Barium: Barium is a metallic element that is used in sparkplugs, fluorescent lamps and getters" in vacuum tubes. Short-term exposure to barium could lead to swelling in brain, muscle weakness, damage to the heart, liver and spleen. Increased blood pressure and hanges in the heart health from ingesting barium over a long period of time has been reported in animal studies. [4]

Beryllium: Beryllium has recently been classified as a human carcinogen because exposure to it can cause lung cancer. [5]

Brominated flame retardants(BFRs): causes hormonal disorder. [6]

Cadmium: Cadmium components may have serious impacts on the kidneys and causes fatal disease like lungs cancer. Cadmium is also believed to cause pulmonary emphysema and bone disorders (osteomalacia and osteoporosis). [7]

CFCs(Chlorofluorocarbons): Reported to cause skin cancer in humans and genetic damage in many organisms. [8]

Chromium: Most chromium (VI) compounds are irritating to eyes, skin and mucous membranes. Chronic exposure to chromium (VI) compounds can cause permanent eye injury and continuous exposure may also lead to DNA damage. [9]

Dioxin: Dioxins are known to be highly toxic to animals and humans because they tend to bio-accumulate in the body and can lead to malformations of the foetus, decreased reproduction and growth rates and cause impairment of the immune system. [10]

Lead: Lead is the fifth most widely used metal after iron, aluminium, copper and zinc in the production of electrical and electronic devices. Short-term exposure to high levels of lead can cause vomiting, diarrhea, convulsions, coma or even death. Continued excessive exposurecan affect the kidneys. It is particularly dangerous for young children because it can damage nervous connections and cause blood and brain disorders. [11]

Mercury: Mercury is one of the most toxic yet widely used metals in the production of electrical and electronic applications. It is a toxic heavy metal that bioaccumulates in the environment causing brain and liver damage if ingested or inhaled. In electronics and lectrical appliances, mercury is highly concentrated in batteries, some switches and thermostats, and fluorescent lamps. [12]

Polychlorinated biphenyls (PCBs): Polychlorinated biphenyls (PCBs) are a class of organic compounds use in a variety of applications, including dielectric fluids for capacitors and transformers, heat transfer fluids and as additives in adhesives and plastics. PCBs have been shown to cause cancer in animals. PCBs is also reported to cause a number of serious health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system and other health effects. PCBs are persistent contaminants in the environment.

Polyvinyl chloride (PVC): When inhaled leads to serious respiratoryproblems. [13]

Selenium: Exposure to high concentrations of selenium compounds cause selenosis.

Biological method of degradation of electric and electronic waste is an emerging alternative for the cleanup of environmental problems. There have been reports on the presence of bacterial strains like *chromobacterium violaceum, Pseudomonas fluorescenceand Bacillus megaterium* that are found to be capable of solubilizing copper and nickel. [14] *Burkholderia sp.*is also evident to solubilize lead and cadmium. [15] *Thiobacillus ferroxidans* and *Leptobacillus ferroxidans* are stated to show solubilization of ferrous iron. [16] These bacterial strains are found to oxidize these elements reducing the metal toxicity. Some cyanogenic bacterial strains produce HCN which detoxifies the hazardous effects of metals. [17] Copper solubilization was performed from the scraps of T.V. circuit board by using mesophillic bacteria [18], acidophilic and cyanogenic bacteria are mostly employed for the solubilization of heavy metals.[19]

Present studies focus on the biodegradation of electronic waste using bacteriawhich consists of various heavy metals like Al, Cu, Zn, Pb, Feand Mn.

MATERIALS AND METHOD

A. Sample Collection

For the isolation of e-waste degrading bacteria soil sample was collected from a landfill in Vellore, Tamil Nadu where majority of solid electronic waste is dumped from most of the parts of Vellore.

Motherboard was used as a source of electronic waste in this study. The motherboard was procured from CTS, VIT University from which (5x5) cm square piece was cut and hammered into powder (Ref. H. Brandl et al. March 2000).

B. Isolation of E-Waste Degrading Bacteria

For the isolation of electronic waste degrading bacteria, nutrient broth was used as media and the following two different methods were followed

a) Enrichment technique: 250ml conical flask containing 100ml nutrient broth with 1g of soil and 0.1g of electronic waste was incubated in a rotary shaker at 120rpm for 30 days. From this 1ml of 10^{-6} serially diluted test tubewas taken and plating was performedonto the nutrient agar medium by spread plate method.

b) Direct inoculation method: The soil was serially diluted and plating was performed from 10^{6} serial dilution onto the nutrient agar medium by spread plate method. After incubation for 12 hrs at (27±2) ˚C colonies were isolated. Purification was performed by quadrant streaking onto nutrient agar medium. [20]

C. Biochemical Characterization

According to Bergey's Manual various biochemical tests were performed: Gram staining, IMVIC, Endospore staining and Catalase test were done for the tested microorganisms to obtain the effective isolate. [21]

D. Seed Culture Preparation

The isolated colonies were inoculated in a test tube containing 6ml of nutrient broth for preparing the seed culture and was incubated overnight at (27±2) ˚C in a rotary shaker at 120rpm. To test the ability of isolate to solubilize, seed culture was inoculated in 100ml nutrient broth containing 0.1g Zn powder.

LGI media was prepared to test the zone of clearance for Zn, Pb and Mn. (LGI media componentsKH2PO4: 0.06g,K2HPO4: 0.02g, MgSO4.7H2O: 0.02g, Na2MoO4: 0.0002g, FeCl3.6H2O: 0.001g, Glucose: 10g, Bromothymol blue(50ml distl. water+0.65g KOH+0.5g BTB powder): 0.5ml, Agar agar: 2.8g), pH 6 and temperature: (27±2)˚C.

E. Zn Solubilization by Effective Isolates

2% of the seed culture of each isolate was inoculated into 100ml of nutrient broth containing 0.1g of Zn powder in two conical flasks VITJS1 and VITJS2. [22]

F. AAS (Atomic absorption spectroscopy)

AAS was performed to spectrophotometriaclly determine the absorbance of ZN by effective isolate VITJS1 and VITJS2. 10 ml of the solubilized broth was centrifuged at 4˚c at 9000rpm for 9 minutes for 5^{th} day and 6^{th} day. 1ml of the supernatant was mixed with 9ml sterile distilled water. Standards solutions for zinc of 200ppm, 400ppm, 600ppm, 800ppm and 1000ppmwas prepared from a zinc stock solution of 1000ppm/L(2.08g dissolved in 1litre is 1000mg/L).[23]

RESULTS

A. Isolation

A total of five different isolates were obtained on Nutrient Agar plates. Based on cellular and morphological characterization two isolates were choose for further studies and were named as VITJS1 and VITJS2.

B. Biochemical Characterization

Based on different biochemical characterization, the isolates were found to be Gram positive rods, non-endospore forming, oxidase and catalase positive.

Table 1: Biochemical characterization of VITJS1

Sl.no.	Name of the test	Result
1.	Methyl Red	+
2.	Voges Proskauer	-
3.	TSI	+
4.	Cimmon's citrate agar	+
5.	Oxidase	+
6.	Catalase	+
7.	Indole	-

C. Zn Solubilization by Effective Isolate

Out of two isolates VITJS1 and VITJS2, only VITJS1 was found to show Zn solubilizing activity. So, VITJS1 was choosed as an effective isolate for carrying out further studies and AAS was performed and graph was plotted with various concentration of Zn on the X-axis and absorbance on Y-axis, AAS results revealed that there was a decrease of 14mg/1000ml of zinc by the action of solubilizing effective isolate.

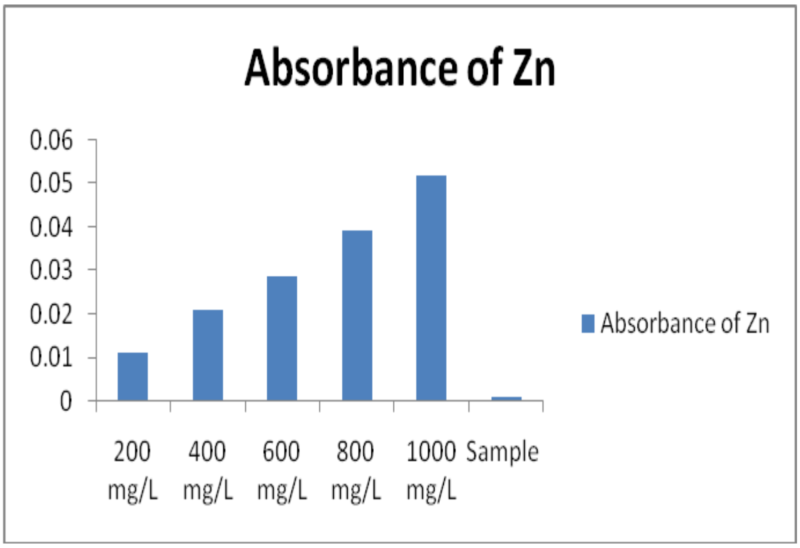

Fig1: Bar graph showing the solubilization of Zn by effective isolate at various concentrations

DISCUSSION

Due to the rapid modernization, there is a huge increase in the use of electrical and electronic gadgets. The unchecked dumping of this e-waste not only pollutes the environment but also hampers human health. There is a soaring need to come up with remediation strategies which is cost effective and environmental friendly. Biological treatment is one such alternative for the isolation of e-waste degrading bacteria. Nutrient Broth (NB) was used as a media carried out his work using NB as a media for the isolation of heavy metals degrading bacteria present in E-waste. [17] VITJS1 proved to be a potent heavy metal degrading bacteria. Solubilization studies showed the ability of VITJS1 in the solubilization of Zn [24] also carried out. AAS is a technique used to know the amount of metal degraded.AAS studies showed that the VITJS1 is able to show absorbance of 0.05 for 1000mg/L So, it can be concluded that VITJS1 is effective in remediation of contamination caused by electronic waste.

CONCLUSION

It can be concluded from present study that VITJS1 is a potent microorganism for the remediation of heavy metals present in electrical and electronic waste. Further studies can be performed in the development of an effective microbial agent using effective isolate VITJS1 for the bioremediation of e-waste contaminated site.

REFERENCES

1. MihaiIrimia-Vladua, b, Eric. D. Głowackib, GundulaVossb, Siegfried Bauera, NiyaziSerdarSariciftci, Green and biodegradable electronics, materials today;15; 7–8 July–August, 2012; Pages 340–346.
2. H. Brandl R. Bosshard M. Wegmann. Computer-munching microbes: metal leaching from electronic scrap by bacteria and fungi.Hydrometallurgy, 2001; 59: 2-3.
3. JeurgZobrist: Mobilization of Arsenite by dissimilarity Reduction of Absorbed Arsenate. Journal of Environmental science technology, 2000; 34: 4747-4753.
4. Ng JC, Wang JP, Shraim A. A global health problem caused by arsenic from natural sources.Chemosphere, 2003; 52: 1353-1359.
5. Centers for Disease Control and Prevention (CDC). Barium toxicity after exposure to contaminated contrast solution–Goias State, Brazil, 2003. MMWR Morb Mortal Wkly Rep, 2003 Oct, 31; 52(43): 1047-8.
6. Lim SR, Schoenung JM. Human health and ecological toxicity potentials due to heavy metal content in waste electronic devices with flat panel displays. J Hazard Mater, 2010; May15; 177(1-3): 251-9.
7. Gosavi A. et al. “Mimicking of Estradiol Binding by Flame Retardants and their Metabolites”. Environmental Health Perspectives, 2013; 121: Issue 1.
8. K. J. Yost.Cadmium, the environment and human health: An overview. Cellular and Molecular Life Sciences, 1984; Volume 40; Issue 2: 157-164.
9. Jonathan R. Llyod and Derek R. Lovely: Microbial detoxification of metals and radionuclides. Current opinion in biotechnology, 2001; 253. Current Opinion in Biotechnology, 2001; 12: 248–253.
10. Dayan, A. D.; Paine, AJ (2001). "Mechanisms of chromium toxicity, carcinogenicity and allergenicity: Review of the literature from 1985 to 2000". Human & Experimental Toxicology, 2000; (9): 439-451.
11. S. Alaluusua, P. Calderara, P.M. Gerthoux, P.L. Lukinmaa, O. Kovero, L. Needham, D.G. Patterson Jr., J. Tuomisto, P. Mocarelli, Developmental dental aberrations after the dioxin accident in Seveso, Environ. Health Perspect, 2004; 112: 1313–1318.
12. HalukBeyenal and Zbigniew Lewandowski. Dynamics of lead immobilization.A journal of the International Water Association, 2004; Volume 38; issue 11: 2621-2794.
13. Horowitz Y, Greenberg D, Ling G, Lifshitz M (2002). "Acrodynia: a case report of two siblings". Archives of disease in childhood Dis Child.Jun, 2002; 86(6): 453.

14. Arnold DL, Mes J, Bryce F, Karpinski K, Bickis MG, Zawidzka ZZ, et al. A pilot study on the effects of Aroclor 1254 ingestion by rhesus and cynomolgus monkeys as a model for human ingestion of PCBs. Food Chem Toxicol, 1990; 28: 847–857.
15. Mohammad A. Faramarzia,1, Marion Stagarsa, Enrico Pensinib, Walter Krebsb, Helmut Brandla. Metal solubilization from metal-containing solid materials by cyanogenic Chromobacteriumviolaceum Institute of Environmental Sciences, Journal of Biotechnology, 2004; 113: 321-326.
16. Oh, C.J., Lee, S.O., Yang, H.S., Ha, T.J., Kim, M.J. Selective leaching of valuable metals from waste printed circuit boards. J. Air Waste Manage. Assoc, 2003; 53: 897–902.
17. L.G. Leduc, G.D. Ferroni, J.T. Trevors, Resistance to heavy metals in different strains of Thiobacillus ferrooxidans, World J. Microbiol. Biotechnology, 1998; 13: 453–455.
18. Wissing, F., 1968.Growth Curves and pH-Optima for Cyanide Producing Bacteria. Physiologia Plantarum, 1968; 21: 589–593.
19. A.B. Bas et al. Outcome of endoscopic band ligation for oesophagealvariceal bleed in patients with chronic liver disease. Gomal Journal of Medical Sciences, 2013; 11: 84-87.
20. Wu S, Sun X, Zhu W, etal. Evidence for GAL3ST4 mutation as the potential cause of pectusexcavatum. Cell research, 2012; 22(12): 1712-5.
21. Veit, H.M., Pereira, C.C., Bernardes, A.M., 2002. Using mechanical processing in recycling printed wiring boards. JOM 45–47(June).
22. Honghui Zhu mail, JianhuaGuo, Meibiao Chen, Guangda Feng, Qing Yao Burkholderiadabaoshanensis sp. nov., a Heavy-Metal-Tolerant Bacteria Isolated from Dabaoshan Mining Area Soil in China. PLOS, 2012.
23. Elena Martinoa, Silvia Perottoa*, Richard Parsonsb, Geoffrey M. Gaddb, Solubilization of insoluble inorganic zinc compounds. Soil Biology & Biochemistry, 2002; 34: 1201–1206.
24. H. Brandle, R. Bosshard, M. Wegmann.Computer-munching microbes: metal leaching from electronic scrap by bacteria and fungi. Hydrometallurgy, 2001; 59: 319-326.