Journal of Education for Pure Science- University of Thi-Qar
Vol.13, No.2 (June., 2023)
Website: jceps.utq.edu.iq *Email: jceps@eps.utq.edu.iq*

DOI: http://doi.org/10.32792/utq.jceps.10.01.01

The role of soil microbial in the remediation of electronic waste

Zainab Abood Sadoon[1], **Saffa Aziz Mouhsen[2]**

zainab.as.@edu.iq safaaaziz@alayen.edu.iq

[1] Scientific Research Center, Al-Ayen University, Thi-Qar, Iraq. Education Directorate of Thi-Qar, Ministry of Education, Iraq

[2] Scientific Research Center, Al-Ayen University, Thi-Qar, Iraq. Education Directorate of Thi-Qar, Ministry of Education, Iraq

Received 3/4/2023, Accepted 15/5/2023, Published 11/6/2023

Abstract:

Undoubtedly, electronic goods made life easier for people and supplied It made life easier for everyone and gave comfort. However ongoing updates, the short lifespan of electronic products, affordable prices, and illegal disposal of electronic waste, as a result, electronic waste has made electronic waste faster growing. This review highlights current bioremediation techniques, bacterial and fungal bioleaching utilize normally occurring microorganisms and their by-products to extract valuable metals, which, because of its affordability, environmental friendliness, and sustainability, is a promising technique. Bacterial species are resistant to high concentrations of heavy metals and organic pollutants were highlighted which have possibly potential remediation properties.

Keywords: Bioaccumulation, Bioleaching, Bioremediation, Biosorption, Electronic Waste

1-Introduction

Globally, some 50 million Mt of e-waste is produced every year, endangering the environment and harming people's health. Only 15% of that is recycled annually; the remainder is dumped in landfills, illegally traded for, burned, or otherwise handled carelessly [1]. In 2030, there will likely be 74 Mt of electronic garbage produced. Consequently, electronic waste poses a serious risk to the environment [2]. Electronic waste poses potential environmental threats and health risks to humans, as it releases many toxic elements into the environment, including cadmium and lead, phosphorus [2,3,4].

Electronics technology has advanced beyond all expectations in terms of manufacturing and invention, making human life dependent on gadgets like cellphones, computers, peripherals, TVs, etc [4]. The electronics waste in Iraq has received little attention. To the best of my knowledge, few studies have been conducted on electronic waste until the moment of writing the research, and there may be others under publication or not yet published. In 2014, a study looked into how households in Duhok City perceived, understood, and attitude toward managing electronic and electrical device trash. For better control of the negative effects, stakeholders can think about replacing hazardous materials in e-waste and modifying equipment [5]. In 2018 Increased pressures have been placed on Small enterprises. In Thi-Qar provenance, enterprises have been escalating. Whereas these enterprises generate rising amounts of electronic waste [6]. Hilal, 2019, was succeeded in extracting Au^{+1}, and Ag^{+1} from electronic waste depending on the adsorption feature (efficiency and capacity) of Polyacrylamide-Kaolin composite [7]. The effectiveness of the adsorption of Au^{+1} was greater than Ag^{+1} from adsorbent element in-situ polymerization via the fourth flotation technique. But as the temperature rises, it somewhat declines [8]. Due to the substantial market shares and numerous foreign firms with branches or agencies in Iraq, the import of goods from these firms has increased. The handling of a significant amount of outdated or flawed goods was another issue brought on by this method. In addition, the government and supervisory roles in this industry are inadequate [9]. In Sulaimania city, after 2003, electronic waste was constitute 0.1% of Municipal solid waste. unfortunately, there are several clear causes, like the public's lack of environmental awareness, which has aggravated the volume of solid waste [10]. This review, explore the green approaches in heavy metal and hazard materials remediation, precisely the biodegradability via the soil microbial community, and suggest a possible application of these approaches.

2- Combined Contamination and Resistant Microbial

At electronic waste polluted sites, heavy metals such as Cd, Cu, Hg, Pb, Zn, as well as Polycyclic aromatic hydrocarbons (PAHs) and polybrominated diphenyl ethers (PBDEs) are common pollutants [11,12,13]. Furthermore, it was discovered that PBDEs played a major role in shaping the variety of the bacterial population [12]. Understanding the relationships between soil microbes and combined pollution would significantly aid in the restoration of damaged ecosystems, a process that is currently only partially successful at the field level. A few research looked into the relationships between soil bacteria and combined contamination with PAHs, PBDEs, and metals (Cd, Cu, Hg, Pb, and Zn) [14]. PBDEs, PAHs, and heavy metals are common at locations with contaminated electronic trash (electronic waste). Overall, bacterial populations in contaminated soil work together to survive. *Rhodoplanes* and *Nitrospira* were able to degrade PAHs and PBDEs through a variety of routes, while *Acinetobacter*, *Citrobacter*, and *Pseudomonas* lowered the community's metal toxicity [15]. Limited reports about combined pollution and its impact on soil microbial communities exist. Many bacterial strains resistant to heavy elements have a tolerance to high concentrations, and which may themselves have biological treatment properties, have been isolated. This review summarized recent studies investigating resistance genera from electronic waste sites (table 1).

Table 1: resistances soil microbial strain of pollutants in e-waste recycling sites.

No.	Author name and date	Removal substances	Mechanism	Dominated strains
1.	Narayanasamy *et al.*, 2021[16]	Pb and Cd	Bioremediation	*Frankia sp.*
2.	Salam *et al.*, 2020 [17]	arsenate (V) up to 0.2M and arsenite (III) up to 0.01M	Bioremediation	*Sporosarcina luteola*
3.	Li *et al.*, 2021[18]	Cd and pb	Bioremediation	*Lysinibacillus sp.*
4.	Utimura *et al.*, 2019 [19]	copper recovery from printed wire boards (PWBs)	Biohydrometallurgica	*Acidithiobacillus ferrooxidans*

5.	Kaur *et al*., 2022 [20]	Fe and Cu	Biosorption & bioleaching.	*Pleurotus florida and Pseudomonas spp.*
6.	Sikander *et al*., 2022 [21]	Ni and Cu (99% and 96%, while Fe, Zn, Al and Mn reached an extraction yield of 89, 77, 70 and 43%,	chemical and microbial leaching	*Acidithiobacillus ferrooxidans, Leptospirillum ferrooxidans, Acidithiobacillus thiooxidans & Aspergillus niger*
7.	Chang *et al*., 2022 [22]	Di-(2-Ethylhexyl) Phthalate	Biodegradation	*Nocardia asteroides*
8.	Razali *et al*., 2021[23]	extract up to 23.36 ppm copper	Bioleaching	*Oryzobacter sp. strain SC*
9.	Rosa *et al*., 2022 [24]	Copper, Yttrium, Palladium	Bioaccumulation	*Aspergillus tubingensis Penicillium glandicola Trichoderma harzianum*
10.	Sun *et al*., 2020 [25]	Hg, Pb, and Cu	Precipitation by H_2S	*Yeast strain W303α*
11.	Abraham *et al*., 2020 [26]	98.6% copper, 64.6% lead and 57.3% nickel.	Bioaccumulation	*Bacillus licheniformis*
12.	Olubode *et al*., 2022 [27]	Co, Cr, Pb	Biosorption	*Bacillus cereus S25*

3-Bioremediation

The process of bioremediation involves using specific plants and microbes to remove pollutants from the environment. The target heavy metals are taken up and metabolized by the plants or/and microorganisms, which makes them less dangerous or non-hazardous. Bioremediation is popular because it is inexpensive, non-intrusive, produces little trash, and is environmentally friendly [28]. Bioremediation of electronic waste treatment can be improved by microbial cooperation. Every management strategy focuses on electronic organic wastes and inorganic components. The organic component is made up of various thermoplastics and thermosetting plastics that contain halogenated materials. Dehalogenation involves microbes in many different ways. The inorganic fraction of electronic waste, which includes both metallic and nonmetallic components, can be managed by microbes during the leaching process [29]. Basically, bioremediation has many mechanisms including bioremediation, biosorption, bioleaching, biodegradation, bioaccumulation, precipitation, and biosorption see (table 1).

Most of the metal-tolerant microbes as used for the remediation, this point of view, in one of the research conducted isolated metal-tolerant bacterial species from the electronic waste contaminated soil sites in the Trichy area. Totally 44 colonies were observed from three soil samples, among them, 6 bacterial genera were obtained, including *Bacillus spp*, *Pseudomonas spp*, *Serratia marcescens*, *Klebsiella pneumonia*, *Micrococcus spp*, and *E. coli* [30].

4-Bioleaching

Bioleaching is a biological process, which is metals dissolution by microbes. Active bioleaching agents of electronic wastes include many nutritional types of bacteria including autotrophs and heterotrophs. Although the exact mechanism by which bacteria bioleach metals is unknown, it is thought to involve redox processes, protonic assault, or chelation. Biotic variables, such as the kind and class of microorganisms, their growth rate, metabolic activity, etc., have an impact on the bioleaching process.

However, a number of abiotic factors have a significant impact on the effectiveness of bioleaching [31].

5- Bioleaching fungi

Presently, Scientists are aware that fungi could participate actively in green technology aimed at recycling valuable elements. Filamentous fungi have already proven successful to use filamentous fungal species' bioleaching and bioaccumulation mechanisms in extraction procedures. In light of the findings, *Aspergillus tubigensis* would make the greatest option for recovering rare earth elements and valuable metals from electronic waste powder. The elements in examined waste with the highest bioconcentration factors are yttrium, copper, and palladium [24]. According to several reports, in the reprocessing of printed circuit boards (PCBs), *Aspergillus niger* can extract copper about 100% of by the bioleaching process [33]. In a comparison between chemical and microbial leaching for multi-metal extraction from PCBs and tantalum capacitor scrap. *A. niger* was utilized in the tests and compared to chemical leaching utilizing certain acids (sulfuric, citric, and oxalic acids). 100% success rate of Cu, extraction, and nearly 85% of Zn, Fe, Al, and Ni were accomplished from PCB and tantalum capacitor scrap samples using sulfuric acid. whereas Filtrate from *A. niger* demonstrated effective solubilization of Cu, Fe, Al, Mn, Ni, Pb, and Zn at an efficiency of 52, 29, 75, 5, 61, 21, respectively and 35% from PCBs specimens and 61, 25, 69, 23, 68, 15 and 45% from tantalum capacitor specimens, respectively [21]. Microorganisms can also be used as a "magic solution" for biodegradation and the cleanup of polluted environments. Today, to efficiently clean up radioactive wastes, microbes and nanotechnology are combined in a process known as nano-bioremediation. Additionally, the application of "genetically modified organisms" in highly contaminated environments makes the microorganism beneficial for human welfare [33].

6-Conclusion

Electronic waste releases many hazardous particles into the environment causing critical health effects in animals and humans. it can be degraded in soil using bacteria and fungi through the bioleaching process. One such environmentally friendly method that has a lot of potential for use in processing electronic waste is bioleaching. Many scientists have used different fungal and bacterial species to recover various precious metals with improved efficiency rates from electronic trash, including copper, gold, and silver. The biological recovery of metals through electronic trash is still in its infancy, however, as the isolated microbial strains have not undergone extensive study and are not particularly specialized to act on a particular type of e-waste. we recommend more research to investigate in soil microbial community properties including; energy and carbon sources and used them in electronic waste remediation.

REFERENCES

[1] **Bharathi, S. D., Dilshani, A., Rishivanthi, S., Khaitan, P., Vamsidhar, A., & Jacob, S. (2022)**. Resource Recycling, Recovery, and Xenobiotic Remediation from E-wastes Through Biofilm Technology: A Review. Applied Biochemistry and Biotechnology, 1-24.

[2] **Chakraborty, S. C., Qamruzzaman, M., Zaman, M. W. U., Alam, M. M., Hossain, M. D., Pramanik, B. K., ... & Moni, M. A. (2022).** Metals in e-waste: Occurrence, fate, impacts and remediation technologies. Process Safety and Environmental Protection, 162, 230-252.

[3] **Sadoon, Z. A., & Enayah, S. H. (2021)**. Serum Heavy Metals Level and OS among e-ic Waste Exposed. Indian Journal of Forensic Medicine & Toxicology, 15(2), 3582-3587.

[4] **Dawood, S. S. (2019).** Future risk assessments of E-waste in Kurdistan Region of Iraq. Academic Journal of Nawroz University, 8(4), 121-135.

[5] **Arif, N., & Afroz, R. (2014).** Electrical and electronic waste management–A case study in University of Duhok, Iraq. Journal of Economics and Sustainable Development, 5(1), 21-27.

[6] **Alziady, A. A. D. J. (2018).** Studying the effect of institutional pressures on managers intentions of Small enterprise in Thi-Qar province to adopt environmental disposal of electronic waste. *Managerial Studies Journal*, *10*(21).

[7] **Hilal, R. H. (2019)**. (Polyacrylamide-Kaolin) Composite Used For Extraction Precious Metals (Au^{+1}, Ag^{+1}) From Electronic Waste Solution by Using Hydrometallurgical Method. Wasit Journal of Engineering Sciences, 7(3), 41-49.

[8] **Hilal, R. H. (2020)**. Removal of Precious Metals from Electronic-Waste by Using Composite Material. In IOP Conference Series: Materials Science and Engineering (Vol. 881, No. 1, p. 012089). IOP Publishing.

[9] **Al-obaidy, O. F. H., Mawlood, S. J., & Al-Dulaimi, M. I. (2021)**. Evaluation of reverse logistics options for international and local companies in Iraq. Indian Journal of Economics and Business, 20(3).

[10] **Hama, A. R., Tahir, T. A., & Ali, B. J. (2021).** A study on solid waste generation, composition and management in Sulaimania city, Kurdistan region, Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 779, No. 1, p. 012049). IOP Publishing.

[11] **Wu, Z., Gao, G., & Wang, Y. (2019).** Effects of soil properties, heavy metals, and PBDEs on microbial community of e-waste contaminated soil. Ecotoxicology and Environmental Safety, 180, 705-714.

[12] **Wu, Y., Song, Q., Wu, J., Zhou, J., Zhou, L., & Wu, W. (2021).** Field study on the soil bacterial associations to combined contamination with heavy metals and organic contaminants. Science of The Total Environment, 778, 146282.

[13] **Pradeepa, R., & Kavitha, K. K. (2020).** Isolation and identification of heavy metal resistant bacteria from an e-waste contaminated soil sites. Intl J Anal Exp Modal Anal, 12, 2259-2265.

[14] **Wu, Y., Song, Q., Wu, J., Zhou, J., Zhou, L., & Wu, W. (2021).** Field study on the soil bacterial associations to combined contamination with heavy metals and organic contaminants. *Science of the Total Environment*, *778*, 146282.

[15] **Wu, Z., Gao, G., & Wang, Y. (2019).** Effects of soil properties, heavy metals, and PBDEs on microbial community of e-waste contaminated soil. *Ecotoxicology and Environmental Safety*, *180*, 705-714.

[16] **Narayanasamy, M., Dhanasekaran, D., & Thajuddin, N. (2021).** Bioremediation of noxious metals from e-waste printed circuit boards by Frankia. *Microbiological Research*, *245*, 126707.

[17] **Salam, M., Varma, A., & Chaudhary, D. (2020).** Novel Arsenic resistant bacterium Sporosarcina luteola M10 having potential bioremediation properties. J Microbiol Exp, 8(6), 213-218.

[18] **Li, W., Fishman, A., & Achal, V. (2021).** Ureolytic bacteria from electronic waste area, their biological robustness against potentially toxic elements and underlying mechanisms. Journal of Environmental Management, 289, 112517.

[19] **Li, W., Fishman, A., & Achal, V. (2021).** Ureolytic bacteria from electronic waste area, their biological robustness against potentially toxic elements and underlying mechanisms. Journal of Environmental Management, 289, 112517.

[20] **Kaur, P., Sharma, S., Albarakaty, F. M., Kalia, A., Hassan, M. M., & Abd-Elsalam, K. A. (2022).** Biosorption and Bioleaching of Heavy Metals from Electronic Waste Varied with Microbial Genera. Sustainability, 14(2), 935.

[21] **Sikander, A., Kelly, S., Kuchta, K., Sievers, A., Willner, T., & Hursthouse, A. S. (2022).** Chemical and microbial leaching of valuable metals from PCBs and tantalum capacitors of spent mobile phones. International journal of environmental research and public health, 19(16), 10006.

[22] **Chang, T. T., Lin, Z. W., Zhang, L. Q., Liu, W. B., Zhou, Y., & Ye, B. C. (2022).** Efficient Biodegradation of Di-(2-Ethylhexyl) Phthalate by a Novel Strain Nocardia Asteroides LMB-7 Isolated From Electronic Waste Soil.

[23] **Razali, M. S., Riyadi, F. A., Akhir, F. N. M., Yuzir, M. A. M., & Hara, H. (2021)**. Isolation and characterization of copper leaching microbes from sanitary landfills for copper bioleaching of waste printed circuit boards.

[24] **Rosa, E., Di Piazza, S., Cecchi, G., Mazzoccoli, M., Zerbini, M., Cardinale, A. M., & Zotti, M. (2022).** Applied Tests to Select the Most Suitable Fungal Strain for the Recovery of Critical Raw Materials from Electronic Waste Powder. Recycling, 7(5), 72.

[25] **Sun, G. L., Reynolds, E., & Belcher, A. M. (2020)**. Using yeast to sustainably remediate and extract heavy metals from waste waters. Nature Sustainability, 3(4), 303-311.

[26] **Abraham, J., Chatterjee, A., & Sharma, J. (2020).** Isolation and Characterization of Bacillus licheniformis Strain for Bioleaching of Heavy Metals. Journal of Applied Biotechnology Reports, 7(3), 139-144.

[27] **Olubode, T. P., Amusat, A. I., Olawale, B. R., & Adekola, F. F. (2022).** Biosorption of heavy metals using bacterial isolates from e-waste soil. African Journal of Microbiology Research, 16(7), 268-272.

[28] **Sandil, S. (2023).** Recent trends in bioremediation of heavy metals. In Metagenomics to Bioremediation (pp. 23-53). Academic Press.

[29] **Pant, D., Giri, A., & Dhiman, V. (2018).** Bioremediation techniques for E-waste management. Waste bioremediation, 105-125.

[30] **RP, K. K. (2020).** Isolation and identification of heavy metal resistant bacteria from an e-waste contaminated soil sites. IJAEMA, 12, 2259-65.

[31] **Minimol, M., Shetty K, V., & Saidutta, M. B. (2020).** Process engineering aspects in bioleaching of metals from electronic waste. Bioprocess Engineering for Bioremediation: Valorization and Management Techniques, 27-44.

[32] **Sharada, H. M., Abdel-Halim, S. A., Hafez, M. A., Elbarbary, T. A., Abdel-Fatah, Y., & Ibrahim, I. A. (2021)**. Bioleaching of Copper from Electronic Waste Using Aspergillus niger.

[33] **Mondal, S., & Palit, D. (2019).** Effective role of microorganism in waste management and environmental sustainability. Sustainable agriculture, forest and environmental management, 485-515.