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ADDED VALUE TO E-PLASTIC: A REVIEW

Nor Azaruddin Husni bin Hj Nuruddin

ABSTRACT

Almost every day we have thrown away gadgets we used to replace with new gadgets. Our reasons are either broken, old model, not working properly or others but certainly the gadget needs to be discarded. How can this problem be overcome? Whether by adding value to the gadget or create a new product from old gadgets. This study aims to see how this problem of added value is overcome.

Keywords: added value, gadgets, e-waste, recycle

INTRODUCTION

Almost every day we have thrown away gadgets we used to replace with new gadgets. Our reasons are either broken, old model, not working properly or others but certainly the gadget needs to be discarded. How can this problem be overcome? Whether by adding value to the gadget or create a new product from old gadgets. This study aims to see how this problem of added value is overcome.

LITERATURE REVIEW

Plastic waste from electrical and electronic equipment (WEEE) grows up exponentially fast in the last two decades. Either consumption increase of technological products, like cellphones or computers, or the short lifetime of this products contributes to this rise generating an accumulation of specific plastic materials such ABS (Acrylonitrile-Butadiene-Styrene), HIPS (High impact Polystyrene), PC (Polycarbonate), among others. All of they can be recycled by themselves. However, to separate them by type is neither easy nor economically viable, then an alternative is recycling them together as a blend. Taking into account that could be a deterioration in final properties, to enhance phase adhesion and add value to a new plastic WEEE blend a compatibilization is needed. In this work, a systematical study of different compatibilizers for blends of HIPS and ABS from WEEE was performed. A screening analysis was carried out by adding two different compatibilizer concentration (2wt% and 20wt%) on a HIPS/ABS physical blend 80/20 proportion from plastic e-waste. Three copolymers were selected as possible compatibilizers by their possible affinity with initial plastic WEEE. A complete characterization of each WEEE was performed and compatibilization efficiency was evaluated by comparing either mechanical or morphological blends aspects. Considering blends analyzed in this work, the best performance was achieved by using 2% of styrene-acrylonitrile rubber, obtaining a compatibilized blend with double ultimate strength and modulus respect to the physical blend, and also improve mechanical properties of initial WEEE plastics. The proposed way is a promise route to improve benefit of e-scrap with sustainable, low costs and easy handling process. Consequently, social recycling interest will be encouraged by both ecological and economical points of view (Vazquez & Barbosa, 2016).

The rise of electronic waste (e-waste) generation around the globe has become a major concern in recent times and its recycling is mostly focused on the recovery of valuable metals, such as gold, silver, and copper, etc. However, e-waste consists of a significant weight fraction of plastics (25–30%) which are either discarded or incinerated. There is a growing need for recycling of these e-waste plastics. The majority of them are made from high-quality polymers (composites), such as acrylonitrile butadiene styrene (ABS), high impact polystyrene (HIPS), polycarbonate (PC), polyamide (PA), polypropylene (PP) and epoxies. These plastics are often contaminated with hazardous materials, such as brominated flame retardants (BFRs) and heavy metals (such as Pb and Hg). Under any thermal stress (thermal degradation), the Br present in the e-waste plastics produces environmentally hazardous pollutants, such as hydrogen bromide or polybrominated diphenyl ethers/furans (PBDE/Fs). The discarded plastics can lead to the leaching of toxins into the environment. It is important to remove the toxins from the e-waste plastics before recycling. This review article gives a detailed account of e-waste plastics recycling and recovery using thermochemical processes, such as extraction (at elevated temperature), incineration (combustion), hydrolysis, and pyrolysis (catalytic/non catalytic). A basic framework of the existing processes has been established by reviewing the most interesting findings in recent times and the prospects that they open in the field recycling of e-waste plastics (Das et al., 2021).

Metals are an essential and critical component of today's society: a moment's reflection on their ubiquitous presence in virtually all energy and material production processes is sufficient to confirm this. Metals play a key role in enabling sustainability through various high-tech applications in society. However, the resources of our planet are limited, as is the strain to which we can subject it in terms of emissions, pollution, and disposal of waste. For these reasons, finding ways to lower the environmental footprint of our collective existence and therefore lowering greenhouse gas and other emissions is a vital priority. The principal theme of this contribution is the maximization of resource efficiency as well as enabling a circular economy (CE) through the recycling of waste electric and electronic equipment, with a focus on precious metals (PMs) (incorporating gold, silver, and the platinum group metals [PGMs]) and the base-metal industry that enables their recycling. The detailed and deep knowledge that is required to understand resource efficiency systemically fully in the context of a CE are discussed and the concepts of design for resource efficiency and design for recycling elaborated on. Specifically, the understanding of product-centric recycling is highlighted, setting it apart from the usual material-centric recycling approaches. The latter focus more on bulk materials and therefore inherently limit the maximal recovery of technologically critical elements, as well as PMs and PGMs. The base metals – principally, copper, cobalt, lead, nickel, tin, and zinc – all play a crucial part in the present society. Increasingly, these are linked in concert to form the crucial carrier metals for the sustainable CE society termed the “web of metals” and “web of products” or, in a more modern paradigm, system integrated metal production–in other words, the process metallurgical Internet of things. This chapter also examines the special and crucial role base metals have in acting as enablers in any recycling efforts, as they also play a key role during recycling, such as copper and lead being the solvent of gold and other PMs and PGMs and release them during refining. Above all, the PMs are key economic enablers for the economic viability of recycling as well as the metallurgical infrastructure (system integrated metal production/Internet of things) that makes it possible to recover PMs and PGMs and their other associated elements (Reuter & van Schaik, 2016).

For the rapid growth of population electrical and electronics equipment waste are generated 20 to 50 million tones in world-wide. Half a tonne of e-waste creates by the resident of advanced country in every year. E-waste contains different toxic substances including metals, plastics and refractory oxides which are hazardous or risky for our environment and human wellbeing, thus e-waste management is an essential. Hence, this review outlined the global status of e-waste and its current progress on management worldwide. An exhaustive survey of literature was made on the latest technological approaches in noble and base metals recovery from waste printed circuit boards (PCBs) of electrical and electronic equipment. An emphasis was given to review the most important features of existing industrial routes associated with the metal recovery systems from PCBs. The discussions of green technologies as alternatives of conventional approaches to obtain precious metals from e-waste were overviewed. The application of microbial bioleaching approaches in the extraction metals from e-waste was highlighted. Finally, the concern for the challenges and barriers associated with the e-waste management process in Bangladesh was outlined (Islam et al., 2020).

Zero waste manufacturing (ZWM) is a concept to support countries transition to a circular economy by developing manufacturing technologies and systems that fully eliminate waste across entire waste value chains possible through reuse and recycling. Implementation of ZWM, particularly in dense urban settings such as Singapore, presents challenges for stakeholders, which stem from issues related to land scarcity, productivity, and labor shortage. A framework to address these challenges is proposed comprising six themes of design for zero waste, smart waste audit and reduction planning, smart waste collection, high-value mixed waste processing, collaborative platform for industrial symbiosis, and waste to resource conversion and recycling. A systematic literature review is used to examine industry technologies and research across the six themes to determine how the technologies can support ZWM. The research reveals that a variety of mature waste measurement, collection, and conversion technologies can be integrated through internet-of-things applications and a collaborative platform for industrial symbiosis to support Singapore and other countries in developing a ZWM ecosystem. This research examines the technical limitations of implementing ZWM technologies in dense urban settings using Singapore as a case study. Future areas of research are then proposed to overcome the implementation barriers so that ZWM can be enabled (Kerdlap et al., 2019)

While significant focus has been placed on the environmental and health impacts of waste electrical and electronic equipment (WEEE) treatment, a gap exists with respect to job creation in WEEE treatment. The creation of employment opportunities, and especially of decent work, is an important factor in the growing green and circular economies. This research investigates potential job creation in the Irish WEEE pre-treatment sector by examining the labour requirements at a certified e-recycling facility which conducts all necessary pre-treatment processes, as detailed in the WEEE Directive, and is currently treating 75% of Ireland's WEEE. The study developed and executed a method of estimating the mass of WEEE associated with full-time job equivalencies per category treated. Through observation and measurement of the methods and time required for each of the pre-treatment steps and using categorisations of WEEE established by United Nations University to assign weights per unit, it was determined that between 338 and 1,967 tonnes were required to equate with one full-time job for the categories large household appliances (LHA), CRT/LCD/LED screens, microwave ovens, and mixed waste. Subsequently, the results were applied to estimate the foregone jobs due to untreated WEEE arising in scrap metal collections. It was found that diversion of this waste to a WEEE pre-treatment facility would result in the creation of more than 12 jobs. This research opens doors to further investigate job creation across European Union (EU) member states and globally using the straightforward and consistently applicable and adaptable methods developed here (McMahon et al., 2021)

E-waste, or waste generated from electrical and electronic equipment, is considered as one of the fastest-growing waste categories, growing at a rate of 3–5% per year in the world. In 2016, 44.7 million tonnes of e-waste were generated in the world, which is equivalent to 6.1 kg for each person. E-waste is classified as a hazardous waste, but unlike other categories, e-waste also has significant potential for value recovery. As a result, it is traded significantly between the developed and developing world, both as waste for disposal and as a resource for metal recovery. Only 20% of global e-waste in 2016 was properly recycled or disposed of, with the fate of the remaining 80% undocumented – likely to be dumped, traded, or recycled under inferior conditions. This review paper provides an overview of the global e-waste resource and identifies the major challenges in the sector in terms of generation, global trade, and waste management strategies. It lists the specific hazards associated with this type of waste that need to be considered in its management and includes a detailed overview of technologies employed or proposed for the recovery of value from e-waste. Based on this overview the paper identifies future directions for effective e-waste processing towards sustainable waste/resource management. It becomes clear that there is a strong divide between developed and developing countries regarding this sector. While value recovery is practiced in centralised facilities employing advanced technologies in a highly regulated industrial environment in the developed world, in the developing world such recovery is practiced in a largely unregulated artisanal industry employing simplistic, labour intensive and environmentally hazardous approaches. Thus, value is generated safely in the hi-tech environment of the developed world, whereas environmental burdens associated with exported waste and residual waste from simplistic processing remain largely in developing countries. It is argued that given the breadth of available technologies, a more systematic evaluation of the entire e-waste value chain needs to be conducted with a view to establishing integrated management of this resource (in terms of well-regulated value recovery and final residue disposal) at the appropriately local rather than global scale (Ilankoon et al., 2018)

The rise of electronic waste (e-waste) generation around the globe has become a major concern in recent times and its recycling is mostly focused on the recovery of valuable metals, such as gold, silver, and copper, etc. However, e-waste consists of a significant weight fraction of plastics (25–30%) which are either discarded or incinerated. There is a growing need for recycling of these e-waste plastics. Most of them are made from high-quality polymers (composites), such as acrylonitrile butadiene styrene (ABS), high impact polystyrene (HIPS), polycarbonate (PC), polyamide (PA), polypropylene (PP) and epoxies. These plastics are often contaminated with hazardous materials, such as brominated flame retardants (BFRs) and heavy metals (such as Pb and Hg).

Under any thermal stress (thermal degradation), the Br present in the e-waste plastics produces environmentally hazardous pollutants, such as hydrogen bromide or polybrominated diphenyl ethers/furans (PBDE/Fs). The discarded plastics can lead to the leaching of toxins into the environment. It is important to remove the toxins from the e-waste plastics before recycling. This review article gives a detailed account of e-waste plastics recycling and recovery using thermochemical processes, such as extraction (at elevated temperature), incineration (combustion), hydrolysis, and pyrolysis (catalytic/non catalytic). A basic framework of the existing processes has been established by reviewing the most interesting findings in recent times and the prospects that they open in the field recycling of e-waste plastics (Das et al., 2021)

The existing practices and opportunities for material recovery from end-of-life (EoL) consumer products depend on multiple factors. Some products are relatively simple in terms of metal and other material mix, while others are very complex often containing high concentration of precious and rare metals. With insufficient scale, feasible options for recycling are significantly limited. The major efforts in managing e-waste in Australia, under the Product Stewardship Act 2011, include the collection services for EoL TVs, computers and related products, through establishing industry-funded co-regulatory agreements. A further progression along the recycling value chain is however hindered by a lack of scale for establishing the full recovery operations in the country, as well as by a lack of domestic application for recovered metals. Based on our previous work of estimating the stocks and flows of electrical and electronic equipment and their metal content, this paper provides further analysis of metal flows and value associated with e-waste. Notably, we estimate how this is currently captured and/or lost, and overview barriers and opportunities for retaining the ‘wealth from waste’ through progression along the metal value chain in Australia (Golev & Corder, 2017).

Improper disposal of electronical waste (e-waste) causes harm to both public health and the environment, and how to effectively recycle and reduce electronical waste has become a common concern around the world. This study focuses on the design of the points system to encourage consumer participation in e-waste recycling programs. Based on the Theory of Planned Behavior (TPB) model, a semi-experimental design method was applied to influence consumer cognition and behavioral intention through information provision in survey design. Two surveys were conducted in two years apart to understand the temporal trend of consumer types and their preferences for the design of e-waste recycling points program. By comparing consumer types before and after the introduction of the points system, the research concludes that the points system has a positive impact on consumers’ environmental consciousness and recycling intention. The results show that consumers generally have a strong sense of environmental protection after the introduction of the recycling points system, and that different consumer types differ significantly on subjective norm, perceived behavioral control, recycling moti- vation, points incentives, points redemption and recycling behavioral intentions. This suggests that the design of the points system can not only promote consumers’ environmental awareness but also stimulate consumers to actively participate in e-waste recycling. Finally, several policy recommendations are discussed to help apply the points system to the empirical design of e-waste recycling program (Zhong et al., 2022).

Waste electrical and electronic equipment (WEEE) or simply e-waste have been gaining attention around the world due to their rapid generation and potential economic values. While several global and regional estimations of e-waste have been conducted, the current and future magnitude of e-waste in Indonesia, the world's fourth largest population, has not been thoroughly assessed. This study aims to provide an estimation and projection of e-waste generation in Indonesia, as well as its potential recoverable metals’ value from 1996 to 2040 to address this gap. An advanced multivariate Input-Output Analysis (IOA) of sales-stock-lifespan model and a dynamic, time-variant lifespan of products through Weibull distribution function were used to provide more accurate and extended estimation of e-waste generation in Indonesia. The results show that Indonesia's e-waste generation is projected to increase from approximately 2.0 (in 2021) to 3.2 million tonnes (in 2040), which corresponds to 7.3 (in 2021) to 10 kg/capita (in 2040). These represent economic values from US$ 2.2 billion to US$ 14 billion of Copper, Gold, Silver, Platinum, and Palladium in the e-waste. This study also maps the distribution of e-waste generation in Indonesia and found that in 2021, the Java Island contributes up to 56% of the total e-waste generation in the country. Lastly, the study proposes a recycling system framework that include possible processing routes and scenarios that integrate mobile/sub-station recycling facilities to existing large metallurgical facilities in the context of Indonesia archipelago (Mairizal et al., 2021)

The benefits of consumer electronic products have transformed every societal sector worldwide. However, the adverse impacts of electronic waste (e-waste) disproportionately affect low-income communities and marginalized ecosystems in nations with economies in transition. The embodied carbon footprint of new electronic products, especially information communication and technology (ICT) devices, is an important source of greenhouse gas (GHG) emissions, accounting for 67%±15% of total lifetime emissions, instigated by mineral mining, manufacturing, and supply chain transportation. We estimate that between 2014 and 2020, embodied GHG emissions from selected e-waste generated from ICT devices increased by 53%, with 580 million metric tons (MMT) of CO_2e emitted in 2020. Without specific interventions, emissions from this source will increase to ~852 MMT of CO_2e annually by 2030. Increasing the useful lifespan expectancy of electronic devices by 50% to 100% can mitigate up to half of the total GHG emissions. Such outcomes will require coordination of eco-design and source reduction, repair, refurbishment, and reuse. These strategies can be a key to efforts towards climate neutrality for the electronics industry, which is currently among the top eight sectors accounting for more than 50% of the global carbon footprint (Singh & Ogunseitan, 2022)

Due to the rapid development in electronic industries and high consumer demand, electrical and electronic equipment have a shorter lifetime in developed and developing countries markets, leading to tons of electronic waste. The waste Printed circuit board (PCBs) contain many valuable metals like gold and copper and hazardous materials like lead. Therefore, recycling the metallic and non-metallic fractions from waste PCBs using environmentally friendly and suitable sustainable resource utilization techniques is in high demand. In this direction, nanotechnology has also been recently used to recover base metals, toxic metals, and precious metals in different sizes and morphologies. This study provides an up-to-date review of research on recovering high added value (HAV) materials from various electronic waste components. These include high purity metals, nanoparticles, nanostructured alloys, nanocomposites, high purity ultrafine particles, and microfibers. It also includes the properties investigated and the potential applications of the obtained HAV products in fields such as wastewater treatment, detection of incessant pollutants, biomedicine, and catalysis. Current challenges faced in scaling up the e-waste derived nanoproducts manufacturing are also discussed in the concluding remarks (Gautam et al., 2022)

REFERENCES

Arize, A. C. (1994). A re-estimation of the demand for money in small developing economy. *Applied Economics*, 26, 217-28.

Blyton, P. & Turnbull, P. (1998). *The Dynamics of Employee Relations*, 2nd ed., London: McMillan Press Ltd.

Wilkinson, R. (1999). Sociology as a marketing feast. In M. Collis, L. Munro, & S. Russell (Eds.), *Sociology for the New Millennium*. Papers presented at The Australian Sociological Association, held at Monash University, Melbourne, 7-10 December (pp. 281-289). Churchill, Victoria: Celts.

Treviño, L. K., & Nelson, K. A. (2007). *Managing business ethics: Straight talk about how to do it right*. Hoboken, NJ: Wiley.

Das, P., Gabriel, J.-C. P., Tay, C. Y., & Lee, J.-M. (2021). Value-added products from thermochemical treatments of contaminated e- waste plastics. *Chemosphere*, *269*, 129409. https://doi.org/https://doi.org/10.1016/j.chemosphere.2020.129409

Gautam, P., Behera, C. K., Sinha, I., Gicheva, G., & Singh, K. K. (2022). High added-value materials recovery using electronic scrap-transforming waste to valuable products. *Journal of Cleaner Production*, *330*, 129836. https://doi.org/https://doi.org/10.1016/j.jclepro.2021.129836

Golev, A., & Corder, G. D. (2017). Quantifying metal values in e-waste in Australia: The value chain perspective. *Minerals Engineering*, *107*, 81–87. https://doi.org/https://doi.org/10.1016/j.mineng.2016.10.021

Ilankoon, I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., & Petersen, J. (2018). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, *82*, 258–275. https://doi.org/https://doi.org/10.1016/j.wasman.2018.10.018

Islam, A., Ahmed, T., Awual, M. R., Rahman, A., Sultana, M., Aziz, A. A., Monir, M. U., Teo, S. H., & Hasan, M. (2020). Advances in sustainable approaches to recover metals from e-waste-A review. *Journal of Cleaner Production*, *244*, 118815. https://doi.org/10.1016/j.jclepro.2019.118815

Kerdlap, P., Low, J. S. C., & Ramakrishna, S. (2019). Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. *Resources, Conservation and Recycling*, *151*(September), 104438. https://doi.org/10.1016/j.resconrec.2019.104438

Mairizal, A. Q., Sembada, A. Y., Tse, K. M., & Rhamdhani, M. A. (2021). Electronic waste generation, economic values, distribution map, and possible recycling system in Indonesia. *Journal of Cleaner Production*, *293*, 126096. https://doi.org/10.1016/j.jclepro.2021.126096

McMahon, K., Ryan-Fogarty, Y., & Fitzpatrick, C. (2021). Estimating job creation potential of compliant WEEE pre-treatment in Ireland. *Resources, Conservation and Recycling*, *166*(October 2020), 105230. https://doi.org/10.1016/j.resconrec.2020.105230

Reuter, M., & van Schaik, A. (2016). *Chapter 53 - Gold – A Key Enabler of a Circular Economy: Recycling of Waste Electric and Electronic Equipment* (M. D. B. T.-G. O. P. (Second E. Adams, Ed.; pp. 937–958). Elsevier. H ttps://doi.org/https://doi.org/10.1016/B978-0-444-63658-4.00053-0

Singh, N., & Ogunseitan, O. A. (2022). Disentangling the worldwide web of e-waste and climate change co-benefits. *Circular Economy*, *1*(2), 100011. https://doi.org/10.1016/j.cec.2022.100011

Vazquez, Y. v, & Barbosa, S. E. (2016). Recycling of mixed plastic waste from electrical and electronic equipment. Added value by compatibilization. *Waste Management*, *53*, 196–203. https://doi.org/https://doi.org/10.1016/j.wasman.2016.04.022

Zhong, H., Zhou, S., Zhao, Z., Zhang, H., Nie, J., & Simayi, P. (2022). An empirical study on the types of consumers and their preferences for E-waste recycling with a points system. *Cleaner and Responsible Consumption*, *7*(March), 100087. https://doi.org/10.1016/j.clrc.2022.100087

Nor Azaruddin Husni bin Hj Nuruddin
Centre for Science and Environment Studies
Institute of Islamic Understanding Malaysia (IKIM)
2, Langgak Tunku, Off Jalan Tuanku Abdul Halim
50480 Kuala Lumpur, Malaysia
Email: azaruddin@ikim.gov.my