SYSTEMATICALLY MODEL OF e-WASTE RECYCLING: A REVIEW

Nor Azaruddin Husni bin Hj Nuruddin

ABSTRACT

As the world has shifted towards the digital age, various technological gadgets such as software or hardware have been created to meet demand. This e-waste (electric and electronic) gadgets have a certain lifespan. In this regard, where does this e-waste go? This study aims to make library reviews from primary sources such as journals, books, and materials from electronic media on how the e-waste recycling model from the house to the collection centre. These selected models are either domestic or overseas.

Keywords: e-waste, model, recycling, electric, electronic

INTRODUCTION

The exponential growth in electronic waste (e-waste) comprising end-of-life electrical and electronic equipment has become a primary environmental concern. E-waste recycling, which includes a systematic collection of e-waste and its treatment for recycling functional materials, offers a valuable tool to minimise the escalating heap of e-waste, supplement the shortage of some primary resources and support the economy. However, depending on the processing methods used for recycling, e-waste can also be a source of toxic substances, such as heavy metals, and persistent organic pollutants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), brominated flame retardants (BFRs), perfluoroalkyl and polyfluoroalkyl substances (PFASs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

A REVIEW

To efficiently harness the benefits of e-waste recycling without jeopardising public health, a holistic approach encompassing improved product design and recycling rate and minimal emission of hazardous e-waste pollutants to the environment is required. This review discusses the opportunities, constraints, and strategies for improved e-waste management. Further, we highlight the recent global trend in e-waste generation and provide an overview of the e-waste recycling process and the impact of e-waste pollutants on human health. (Ahirwar & Tripathi, 2021)

A circular economy is a sustainable economic development model. It replaces the traditional economic development model that relies heavily on resource consumption and waste generation. A circular economy is significant to the waste electrical and electronic equipment industry as e-waste contains toxic substances and precious metals. While previous review studies focused on specific aspects of the WEEE industry (e.g., "4R" circular economy strategies), these studies offer little details on how circular economy practices affect the development of the environment and economy in the waste electrical and electronic equipment industry.

This study examines "10R" circular economy strategies to advance knowledge of the existing literature focusing on "4R" circular economy strategies. This paper conducts a systematic literature review on 208 studies and uses citation network analysis to examine specific circular economy practices in the waste electrical and electronic equipment industry. The citation network analysis identified five major research domains (i.e., "e-waste management systems and practices", "e-waste legislation and its components", "extended producer responsibility schemes", "recycling critical materials from e-waste", "circular economy strategies for the waste electrical and electronic equipment industry"). Based on these results, this study conducts a primary path analysis to reveal ten major topics (ie-waste recycling system, exploring untapped e-waste, compliance assurance of stakeholders, e-waste reverse logistics, reward and punishment mechanisms in extended producer responsibility system, verifying the rationality of product classification, recycling critical materials from urban mines, setting a specific target for preparation for reuse, "10R" strategies applied in the intelligent factory, consumer attitude toward remanufactured/refurbished/repurposed system and the resultant products). Finally, this paper proposes future research directions and provides managerial and policy implications for researchers and practitioners (Pan et al., 2022)

Solid waste generation and its impact on human health and the environment have long been a matter of concern for governments across the world. In recent years, there has been increasing emphasis on resource recovery (reusing, recycling, and extracting energy from waste) using more advanced approaches such as artificial intelligence (AI) in Australia. AI is a powerful technology increasingly gaining popularity and application in various fields. AI techniques offer innovative alternative approaches to solid waste management (SWM). Although there are previous studies on AI technologies and SWM, no study has assessed the adoption of AI applications to solve the various SWM problems for sustainable waste management in Australia. Moreover, there are inconsistencies and a lack of awareness of how AI technologies function with their application to SWM. This study examines the application of AI technologies in various areas of SWM (generation, sorting, collection, vehicle routing, treatment, disposal, and waste management planning) to enhance sustainable waste management practices in Australia. Various databases are collected and analysed. The study focuses on the adoption of AI applications on SWM, compares the performance of AI applications, explores the benefits and challenges, and provides best practice recommendations on how resource efficiency can improve economic, environmental, and social outcomes. This study found that AI-based models have better prediction abilities when compared to other models used in forecasting solid waste generation and recycling. Findings show that waste generation in Australia has been steadily increasing and requires upgraded and improved recovery infrastructure and the appropriate adoption of AI technologies to enhance sustainable SWM. Australia's adoption of AI recycling technologies would benefit from a national approach that seeks consistency across jurisdictions while catering for regional differences. This study will help researchers,

governments, policymakers, municipalities, and other waste management organisations increase current recycling rates, eliminate manual labour, reduce costs, maximise efficiency, and transform how we approach solid waste management.(Andeobu et al., 2022).

Brazil, the largest producer of e-waste in Latin America, recently enacted a new law for the reverse logistics of this waste. Implementing the new regulation will require the integration of different stakeholders to overcome existing barriers, including a lack of awareness, data, and technical expertise in e-waste management. A reverse logistics model is a potential solution to these barriers (Santos & Ogunseitan, 2022)

Despite the United States adopting electronic waste recycler certification schemes, recyclers might engage in dishonest practices. To better understand mechanisms that may encourage honest electronics end-of-life management, we develop a framework to analyse the decision between an ethical choice or has some probability of being caught. Building an analytical decision tree model under which a recycler maximises expected returns, we explore the influence of supervision on the choices a recycler faces and provide an analytical solution that describes the boundaries that separate those choices. Using our framework, we systematically catalogue which interventions may help and which may not. The model suggests that direct unqualified subsidies to recyclers may not be particularly effective, although properly targeted subsidies have promise. We also find substitution effects between increasing the cost of fraud and decreasing the costs of proper electronic waste recycling. Increasing the cost of fraud can serve as a policy instrument to produce effects like reducing a recycler's costs from engaging in honest behaviour. We also discuss the role of digital fraud prevention technologies, such as blockchain, as another mechanism to help achieve sustainability outcomes in e-waste management while lowering the costs of third-party supervision (Salmon et al., 2021)

There is no formal system in place for household e-waste management. However, according to Natural Resources and Environment Ministry in Malaysia, e-waste from industries is controlled and regulated. Buyers collect E-waste from non-governmental organisations or collectors, but they improperly dismantle e-waste, which can cause environmental and health hazards. Malaysia was estimated to generate 53 million pieces of e-waste in 2020. Therefore, a proper system is required to control hazardous substances such as cadmium, mercury, chromium, zinc, lead, silver, and copper found in e-wastes that cannot release into the environment. The present study aims to determine laptop disposal practices. Data from 123 respondents through structured questionnaires and open-ended questions from individuals who own laptops were collected. The findings highlight that individual awareness of laptop disposal practices and laptop users positively influence the conviction of laptop disposal practices. An extensive e-waste management model can resolve challenges arising from the e-waste crisis. In particular, the proposed model acts as a guide for upstream and downstream reduction of e-waste generation through green design to succeed in e-waste environmentally sound management system (Jayaraman et al., 2019)

The E-waste problem puts pressure on environmental agencies, the government, and original equipment manufacturers to develop and innovate environment-friendly e-waste mitigation strategies. Moreover, increasing producer responsibility, informal recycling practices and disposal issues have given attention to adopting mitigation strategies to implement the e-waste management system successfully. This study acknowledges the critical approach to recovering resources and processing and treating toxic and hazardous components of e-waste mitigation and management, which is an immediate and existing challenge for India. A combined framework based on the grey concept and DEMATEL technique has been proposed in this work to determine the interdependence among the e-waste mitigation strategies (MS) by cause/effect analysis. This study has revealed that 'top management initiation and commitment towards return management' is the most imperative driving strategy in e-waste management and control. It also influences the other existing techniques. This work has also highlighted that e-waste mitigation can be effective if it concentrates on practically implementing e-waste policies, directives, and regulations. The cause-effect relationships are helpful to the managers, Government agencies and policymakers to learn crucial causal strategies that require imperative emphasis in dealing with e-waste issues in India. A sensitivity analysis can test the robustness of the proposed framework (Garg, 2021)

This paper proposes a novel algorithm for establishing a standard methodology to manage and refurbish e-waste called E-waste Management and Refurbishment Prediction (EMARP), which refurbishing industries can adopt to improve their performance. Waste management, mainly e-waste management, is a serious issue nowadays. Computerisation has been into waste management in different ways. Much of the computerisation has happened in planning the waste collection, recycling and disposal process and managing documents and reports related to waste management. This paper proposes a computerised model to make predictions for e-waste refurbishment. They are reusing the standard components, thus minimising wastage. Simulation of the model analysed the accuracy of the system's predictions. The model accommodated the real-world scenario (Resmi & Fasila, 2017)

Wastes coming from electrical and electronic equipment (EEE), known as e-waste, is a significant concern because of its alarming increase and the hazardous substances within them that could cause harm to humans and the environment if not properly treated. In developing countries, e-waste is collected and recycled by the Informal waste sector (IWS), which neither has the proper training nor equipment/facility. Reverse logistics of e-waste and the integration of the IWS need to minimise adverse effects. A mixed integer multi-objective linear programming reverse logistics model was developed in this study to integrate the two waste sectors and address the economic, environmental and health issues brought about by e-waste using different recovery options. This model uses specific options, especially regarding the amount to the IWS, as compensation for no longer treating and integrating with the formal waste sector. Producers are compulsory to treat vast amounts of e-wastes and may force to use the IWSs as treatment facilities (Li & Tee, 2012)

Electronic waste (e-waste) contains various electronic components, e.g., metals, non-metals, plastics, cables, etc. The excessive generation of e-waste has become a significant concern in the last few decades. The current global e-waste generation is 57.4 million metric tons (MMT) annually. Asia produces the highest amount of e-waste (24.9 MMT), followed by America, Europe, Africa, and Oceania. In Bangladesh, e-waste makes from two sources: its consumption of electronic devices, which is 0.6 MMT, and imported e-waste from shipbreaking yards, which is 2.5 MMT in 2021. However, inadequate information on the current state of e-waste generation and management systems in Bangladesh has created a void in establishing the future direction for properly handling e-waste. This work analysed Bangladesh's perspective on e-waste. The discussion here is on the environmental, health and economic of e-waste. The government already have legislation regarding e-waste. The life cycle assessment (LCA) and material flow analysis (MFA) have established e-waste management models. Moreover, a holistic approach to understanding the possible hazards, the economic feasibility of e-waste processing and viable management models for e-waste in Bangladesh was

endeavoured in this work to propose systematic future directions and recommendations to improve the current e-waste scenario of Bangladesh (Roy et al., 2022)

Significant loss of valuable resources and increasing burdens on landfills are often associated with a lack of proper planning in waste management and resource recovery strategy. A sustainable waste management model is thus urgently needed to improve resource efficiency and divert more waste from landfills. This paper proposes a comprehensive system model using the stock-and-flow diagram to examine the current waste management performance and project future waste generation, treatment, and disposal scenarios, using England as a case study. The model comprises three integrated modules representing household waste generation and collection, waste treatment and disposal, and energy recovery. In 2035, landfill waste composition to 10%. However, it incurs higher capital investment and gate fees. Alternative case scenarios that promote recycling instead of energy recovery result in lower capital investment and gate fees. Complete elimination of the food and organic fraction from the residual waste stream will help meet the 65% recycling target by 2035. In light of the need for achieving a more circular economy in England, enhancing material recovery through reuse and recycling, reducing reliance on energy-from-waste and deploying more advanced waste valorisation technologies should be considered in future policy and planning for waste management (Ng & Yang, 2023)

This article presents a waste management model for civil construction based on the recycling and reuse of aggregates. Recycling alternatives already used in the studied region were used to define the sum that would compose the model, judging them through the hybrid method composed by Fuzzy TOPSIS and Shannon Entropy. The model was implemented in a case study in the South of Brazil to demonstrate empirical evidence. The results showed an approximation of public entities with universities, research centers, and private companies contributing to the region's environmental, economic, and social development. In implementing the model, many benefits can be added, such as reduced pollution, a cleaner environment, and income generation through commercialising the aggregate. This study brings practical and theoretical contributions, helping formulate strategic guidelines in the public sphere for the correct destination and reuse of waste and contributing to cities' sustainability (Silva et al., 2022).

CONCLUSION

The expeditious developments in technology along with the demand for a high-standard living have resulted in massive production of electronic gadgets, which eventually lead to the generation of huge quantities of obsolescence. With the exponential expanding output of computer hardware, efficient disposal of the electronic waste (E-waste) generated by the Information and Communication Technology (ICT) sector has become a serious concern. The ICT sector generates a major amount of E-waste, but its management strategies are not well defined. The most severe problem associated with these wastes is their informal recycling and improper disposal, threatening the environment and human health. On the other hand, these wastes also provide an opportunity for the recovery of metals and the generation of valuable products. Supercritical fluid technology provides an attractive alternative for the sustainable management of e-waste and plastic waste, as well as resource recovery from these wastes. Therefore, the present review focuses on the applications and potential of supercritical fluid technology for resource recovery from these wastes. The review article presents a comprehensive discussion about the generation and composition of e-waste and plastic waste, the principle of supercritical fluid technology, and the application of various supercritical solvents such as CO2, water, and alcohol for resource recovery from e-waste and plastic waste. Finally, the economic aspect of supercritical fluid technology is also critically reviewed, and a comparative economic analysis with existing technologies is presented. Based on critical analysis, it is observed that supercritical fluid technology provides a viable route for the treatment of both e-waste and plastic waste. However, the pilot-scale studies are not reported, and there is a need to further explore the supercritical fluid technology to make a strong case for industrial application.

REFERENCES

Ahirwar, R., & Tripathi, A. (2021). E-waste management: A review of recycling process, environmental and occupational health hazards, and potential solutions. *Environmental Nanotechnology, Monitoring & Management*, *15*, 100409. https://doi.org/10.1016/j.enmm.2020.100409

Andeobu, L., Wibowo, S., & Grandhi, S. (2022). Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review. *Science of The Total Environment*, *834*, 155389. https://doi.org/https://doi.org/10.1016/j.scitotenv.2022.155389

Garg, C. P. (2021). Modeling the e-waste mitigation strategies using grey-theory and DEMATEL framework. *Journal of Cleaner Production*, *281*, 124035. https://doi.org/10.1016/j.jclepro.2020.124035

Jayaraman, K., Vejayon, S., Raman, S., & Mostafiz, I. (2019). The proposed e-waste management model from the conviction of individual laptop disposal practices-An empirical study in Malaysia. *Journal of Cleaner Production*, *208*, 688–696. https://doi.org/10.1016/j.jclepro.2018.10.125

Li, R. C., & Tee, T. J. C. (2012). A Reverse Logistics Model For Recovery Options Of E-waste Considering the Integration of the Formal and Informal Waste Sectors. *Procedia - Social and Behavioral Sciences*, *40*, 788–816. https://doi.org/10.1016/j.sbspro.2012.03.266

Ng, K. S., & Yang, A. (2023). Development of a system model to predict flows and performance of regional waste management planning: A case study of England. *Journal of Environmental Management*, *325*(PB), 116585. https://doi.org/10.1016/j.jenvman.2022.116585

Pan, X., Wong, C. W. Y., & Li, C. (2022). Circular economy practices in the waste electrical and electronic equipment (WEEE) industry: A systematic review and future research agendas. *Journal of Cleaner Production*, *365*(May), 132671. https://doi.org/10.1016/j.jclepro.2022.132671

Resmi, N. G., & Fasila, K. A. (2017). E-waste Management and Refurbishment Prediction (EMARP) Model for Refurbishment Industries. *Journal of Environmental Management*, *201*, 303–308. https://doi.org/10.1016/j.jenvman.2017.06.065

Roy, H., Rahman, T. U., Suhan, M. B. K., Al-Mamun, M. R., Haque, S., & Islam, M. S. (2022). A comprehensive review on hazardous aspects and management strategies of electronic waste: Bangladesh perspectives. *Heliyon*, *8*(7), e09802. https://doi.org/10.1016/j.heliyon.2022.e09802

Salmon, D., Babbitt, C. W., Babbitt, G. A., & Wilmer, C. E. (2021). A framework for modeling fraud in E-waste management. *Resources, Conservation and Recycling*, *171*(May), 105613. https://doi.org/10.1016/j.resconrec.2021.105613

Santos, S. M., & Ogunseitan, O. A. (2022). E-waste management in Brazil: Challenges and opportunities of a reverse logistics model. *Environmental Technology and Innovation*, *28*, 102671. https://doi.org/10.1016/j.eti.2022.102671

Silva, D. J. C. da, Schaefer, J. L., Baierle, I. C., Veiga, C. P. da, & Júnior, A. N. (2022). Proposition of the waste management model. *Resources, Conservation & Recycling Advances*, *15*(September), 200114. https://doi.org/10.1016/j.rcradv.2022.200114

Nor Azaruddin Husni bin Hj Nuruddin
Centre of Science and Environment Studies
Institute of Islamic Understanding Malaysia
Email: azaruddin@ikim.gov.my