



Transforming E-Waste Management: Challenges and Opportunities

Avishek Khanal ^a, Pasang Sherpa ^b, Prakriti Chataut ^c, Ashish Khanal ^{d, e}, Suja Giri ^{e, *}

^a Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal.

^b Faculty of Management, Tribhuvan University, Kathmandu, Nepal.

^c Institute of Forestry, Hetauda, Nepal.

^d Department of Sustainable Engineering, Teri School of Advanced Studies, New Delhi, India.

^e Global Research Institute and Training Center, Kathmandu, Nepal.

*Corresponding Author Email: girisuza@gmail.com

DOI: <https://doi.org/10.54392/irjmt2429>

Received: 09-09-2023; Revised: 22-01-2024; Accepted: 11-02-2024; Published: 23-02-2024



Abstract: The production of electronic waste (e-waste) has reached alarming levels globally, posing significant environmental, economic, and health risks. This review paper comprehensively analyzes the challenges, impacts, and potential solutions associated with e-waste management in developing nations. It highlights the urgent need for proper regulations, infrastructure development, and public awareness to address the growing problem of e-waste. The paper identifies gaps in current research, such as the lack of concrete recommendations and practical solutions, and aims to provide a foundation for future studies to propose strategies for improving e-waste management practices. The findings emphasize the environmental effects of e-waste and the negative consequences on disadvantaged communities, particularly in underdeveloped regions. Furthermore, the review highlights the importance of transitioning to a circular economy and the economic opportunities presented by e-waste, which contains valuable metals that can be recovered and recycled. The paper calls for the formulation of specific policies focusing on the 3Rs (Reduction, Reuse, and Recycle) and the implementation of provisions such as pollution taxes to reduce e-waste and promote responsible consumption. By addressing these challenges and offering sustainable solutions, effective e-waste management can mitigate environmental risks, protect human health, and contribute to a circular economy.

Keywords: Circular economy, E-waste management, Infrastructure, Recycling, Regulations

1. Introduction

Globally, the production of electric and electronic devices has reached unprecedented levels, resulting in the generation of a significant amount of unmanaged toxic electronic waste (e-waste). E-waste refers to discarded electrical or electronic equipment (EEE) that can be recycled, refurbished, and reused. The alarming rate of e-waste generation is a growing concern, with over 50 million metric tons produced annually, averaging 7 kg per capita. This trend has seen a staggering 60% increase in e-waste generation from 2010 to 2019, and projections estimate that the annual production will reach 75 million metric tons by 2030.

The improper management of e-waste poses severe negative effects on the environment, economy, and human health. Hazardous substances, including cadmium, chromium, lead, and antimony, are present in e-waste, and if not properly disposed of, these toxins can leach into the soil and water, causing contamination [1]. However, e-waste also contains valuable metals such as gold, silver, palladium, and copper that can be reprocessed. E-waste comprises over 60% of these

metals, which presents an opportunity for sustainable resource utilization [2]. Therefore, managing e-waste in an environmentally friendly and economically viable manner is crucial to protect the environment, human health, and to reduce the overall volume of e-waste generated annually.

One of the significant concerns regarding e-waste is the impact it has on disadvantaged communities, particularly in underdeveloped regions. These communities are at greater risk of health and environmental problems due to transboundary e-waste trafficking, as they heavily rely on these materials for their livelihoods and come into frequent contact with them [3]. Studies have shown that a majority of women and children work in the e-waste recycling industry, exposing them to potential hazards [3]. Additionally, the use of informal sectors for e-waste management in low-income countries, such as China, where workers are hired at low wages and employ primitive techniques, further exacerbates the health and environmental risks [4].

The linear model of resource consumption, characterized by the take-make-consume-dispose pattern, contributes to the overuse of resources and pollution of the environment [5]. To address this issue, transitioning to a Circular Economy (CE) is necessary, where products are reused and recycled to reduce CO₂ emissions and raw material consumption [6]. CE serves as a guiding principle to attain numerous sustainable development goals (SDGs) and advocates for a collaborative sharing economy that optimizes material resources through cooperative engagement, resulting in the generation of increased employment opportunities [7]. However, the adoption of a circular economy requires significant restructuring of the current working system, which can potentially disrupt the economy.

More than 60% of e-waste consists of metals like iron, copper, aluminum, gold, and others, with pollutants making up 2.70% [2]. Due to the significant toxicity of these pollutants, especially during uncontrolled burning or recycling, the Basel Convention recognizes e-waste as hazardous. The convention has established a framework to regulate the cross-border transportation of such hazardous waste. The improper disposal and treatment of e-waste have significant environmental consequences. E-waste contains toxic chemicals such as lead, mercury, and other heavy metals and flame-retardants, which contaminate the soil, air, and water resources [8]. The release of deadly toxins like dioxins during transportation, dismantling, and burning of e-waste further contributes to environmental pollution. These toxins have adverse effects on vegetation, animals, and human health. The contaminated soil, water, and air pose risks to animals and humans through the food chain, making them susceptible to fatal illnesses [9].

Addressing the challenges posed by e-waste requires effective solutions and a comprehensive understanding of the current situation through accurate data. Quantitative information on the import, sale, and use of EEE, as well as mapping of material flows within the existing recycling system, is crucial [10]. Additionally, conducting assessments of current waste management scenarios and their potential impacts using scientific tools like life cycle assessment can provide valuable insights. The formulation of specific policies addressing e-waste management, focusing on the 3Rs (Reduction, Reuse, and Recycle), and implementing provisions such as pollution taxes can help reduce e-waste and encourage responsible consumption [11].

The sustainable management of e-waste not only mitigates environmental and health risks but presents economic opportunities. E-waste contains valuable metals worth an estimated 60 billion US dollars, and their recovery through modern recycling processes could benefit the national economy, create employment opportunities, and contribute to a circular economy [12]. By incinerating the toxic components with energy

recovery and recovering heavy metals, the environmental impact of e-waste can be significantly reduced [1]. The informal sector thrives in the e-waste domain within numerous developing nations. Existing deficiencies in environmental management, coupled with a robust demand for used electronic devices and the prevalent practice of selling e-waste to independent collectors, contribute to the flourishing informal recycling industry [4]. A new economic sector is emerging focused on the trade, repair, and recovery of materials from obsolete electronic devices. While it serves as a means of livelihood for both urban and rural communities, it frequently poses significant risks to both humans and the local environment [2].

The significance of this review paper lies in its comprehensive analysis of the environmental effects and challenges associated with e-waste management in developing nations. It brings together various studies from different regions, highlighting the urgent need for proper regulations, infrastructure development, and public awareness to address the growing problem of e-waste. The novelty of this review lies in its examination of specific gaps in existing research, such as the lack of concrete recommendations and practical solutions to overcome the challenges of e-waste management. By identifying these gaps, the paper aims to provide a foundation for future research that can propose tailored strategies for improving e-waste management practices in developing countries. The objectives of this review paper include raising awareness about the environmental impacts of e-waste, identifying gaps in current research, and laying the groundwork for future studies to develop effective and sustainable solutions for e-waste management in developing nations.

2. Methodology

This review paper aims to provide a comprehensive analysis of global e-waste management, addressing challenges, impacts, and potential solutions. The research was conducted in collaboration with the Global Research Institute and Training Center, with the participation of multiple researchers. The initial phase involved an extensive literature search using various databases such as Google Scholar, Research Gate, NepJol, Science Direct, and Springer. The chosen keywords included "e-waste management," "global e-waste issues," "importance of e-waste management," "current e-waste generation," "challenges in e-waste management in Nepal," "barriers to circular economy," and "e-waste practices in Nepal". A total of 53 research papers were reviewed, covering a diverse range of topics related to e-waste management. For this study, the literature published within the last 15 years has been predominantly considered to ensure the inclusion of the most up-to-date research and developments in the field of e-waste management.

The identified articles underwent a screening process based on titles and abstracts to ascertain their relevance. Articles meeting the predefined inclusion criteria were then selected for in-depth review. The reviewed literature was systematically categorized according to thematic relevance, facilitating a structured analysis of challenges, impacts, and potential solutions in the aspect of global e-waste management. The conclusions presented in the review paper were derived through a synthesis of findings extracted from the selected literature.

3. Findings and Discussion

3.1 Environmental Effects and Challenges of E-Waste Management

With the rapid advancement of technology and innovation, the management of e-waste has become a crucial environmental concern. Several studies have explored the effects of e-waste processing on the environment and human health, particularly in developing nations where informal and incorrect e-waste management practices are prevalent.

A study highlight the increasing production of e-waste and its multiple impacts on our lives and the environment [14]. The study contributes to raising awareness about the growing problem of e-waste and the importance of implementing appropriate management practices. Another study [14] examines the current state of waste management, focusing on the environmental effects of heavy metals, dangerous compounds, and carcinogens found in e-waste. It discusses various disposal techniques such as landfills, acid baths, and incineration.

There is need for proper regulations and systems to ensure the safe and efficient management of e-waste [15]. There is lack of legal limits and e-waste collection systems as significant obstacles to effective e-waste management [16]. There is inadequacies in existing Philippine laws and mechanisms for e-waste management from a policy and practical perspective [17]. The study identifies gaps in the regulatory framework and the need for better coordination among stakeholders. While these studies highlight the challenges associated with e-waste management, they could benefit from more specific and practical recommendations.

The government collaborate with private businesses through public-private partnerships (PPP) to establish a sustainable infrastructure for e-waste management [18]. While the PPP model presents a potential solution, there is a potential challenge of implementing such partnerships in the specific context of e-waste management. A study in Ghana found that the financial constraints hinder the adoption of sustainable technologies and recommend government support through subsidies [19].

The review of the literature reveals that e-waste management is a pressing environmental issue in developing countries, including Sri Lanka, India, Bangladesh, and Ghana. There are difficulties in managing e-waste in Sri Lanka, including inadequate formal collection channels and limited knowledge of health risks and environmental effects [20]. It suggested the implementation of specialized policies and legal procedures to establish precise standards for e-product lifecycle management. The challenges faced by Bangladesh, such as improper disposal of e-waste on open soil and bodies of water due to weak regulations is common [21]. The author recommends taking concrete steps to prevent e-waste production and ensure proper disposal.

Waste management is a major issue in metropolitan areas of Nepal, with the need for effective enforcement of current policies and regulations [22]. A study highlighted the importance of government intervention and the enforcement of existing waste management regulations [23]. The absence of data regarding waste generation adds to the difficulty experienced by planning authorities in devising efficient strategies for the sustainable handling of waste in Nepal [24, 25]. The lack of proper source segregation and an inefficient collection system in Nepal has resulted in a significant amount of waste ending up at landfill sites [26].

At present, Nepal does not have a separate law pertaining to the management of e-waste, nor does it have the supporting infrastructure to combat the growing problem [10]. An estimated 1000 people, handle recycled items including the e-wastes informally, most of whom belong to the poor, marginalized, disadvantaged, and vulnerable social groups [10]. They are provided with low wages and no protective clothing, which exposes them to toxic chemicals. Due to the absence of regulatory and supervisory bodies in Nepal, informal waste workers, who are mobile and challenging to document, confront notable occupational health hazards inherent to their tasks [27, 28]. E-waste consists of many toxic and non-biodegradable substances such as Cadmium (Cd), Mercury (Hg), Chromium (Cr), Lead (Pb), and Antimony (Sb). In addition, the combustion of e-waste releases harmful gases such as polychlorinated biphenyls (PCBs), furans (PCDD/Fs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-dioxins and brominated flame retardants (BFRs) which upon entering our food chain can cause problems in pregnancy and Breastfeeding, cause endocrine disruptions and cancer [3]. The BFRs disrupt hormonal activities and cause chronic illnesses like asthma and skin diseases. Even though e-waste is a highly alarming concern, few people are aware of its adverse consequences. The government is yet to formulate any specific e-waste management policies or any appropriate guidelines and regulations for the proper

disposal of e-waste [11]. The 2019 act of Nepal prohibits the importation of harmful electronic products from developed countries [29].

To address the challenges of managing electronic waste in developing nations, a study argues for assistance from United Nations (UN) agencies on a global scale [8]. The article emphasizes the need for advanced technology and legislative protections to mitigate the environmental hazards of e-waste. There is need of development of effective and sustainable e-waste management techniques to recover valuable resources [30]. However, there is lack of specific recommendations regarding the assistance UN agencies can offer to developing nations [8].

The compilation of diverse studies highlights the pressing challenges entailed in managing e-waste amid rapid technological progress. Particularly in developing nations, the consequences of inappropriate e-waste disposal practices on the environment and human health are evident. There is lack of effective regulations and suitable systems, leading to a significant obstacle in achieving safe and efficient e-waste management. Inadequacies in existing policies and frameworks further underscore the complexities in addressing the issue. The prevailing lack of proper collection mechanisms and formal disposal avenues compounds the challenge, perpetuating hazardous disposal practices. Moreover, the alarming situation in regions like Nepal reveals the dire circumstances faced by informal waste workers, who confront health risks due to a lack of protective measures.

3.2 Opportunities for Sustainable E-Waste Management

E-waste has garnered significant attention recently due to its detrimental impact on human health and the environment, emerging as a major environmental concern. A study emphasized the imperative need for effective policies, regulations, and infrastructure development to achieve more sustainable e-waste management in developing nations [16]. However, there exists variability in the scope and focus of these studies, with some offering more precise recommendations than others offer. Furthermore, further research is warranted to investigate the challenges and opportunities associated with implementing e-waste management strategies in developing nations, particularly within the framework of the United Nations' role in addressing this issue on a global scale.

In the context of India, the absence of legal limitations and functional e-waste collection systems as significant obstacles, advocating for a holistic approach that integrates effective policies, regulatory frameworks, and infrastructure development to foster more sustainable e-waste management [16]. However, while highlighting the necessity for effective policies, regulations, and infrastructure, these studies present

disparities in their scope and focus, with varying degrees of specificity in recommendations.

Conversely, in Kenya, a case study that illuminated the challenges encountered in managing municipal solid waste [31], identified deficiencies in MSW collection and disposal services, particularly in suburban areas populated by urban poor, rural migrants, and unemployed individuals. The authors proposed tailored solutions specific to certain areas to address municipal solid waste management issues. Additionally, a study evaluated the recycling of e-waste in China and India, with a focus on both formal and informal sectors [32]. Their findings revealed that cultural traditions, competition from the informal sector, and unresolved regulatory gaps hindered the effectiveness of e-waste formalization programs and technology transfer pilots. While a study provided insights into the challenges related to municipal solid waste management in developing nations, its applicability is constrained by its confinement to Kenya [31]. Similarly, a study of the formal and informal e-waste recycling sectors in China and India offered valuable insights [32], but another study [31] lacked specific suggestions for crafting location-specific solutions, diminishing its practical utility.

In the pursuit of understanding effective solid waste management, numerous case studies have been conducted to evaluate implementation strategies. A study [33] undertook a waste characterization study at Istanbul Airport to assess the efficacy of waste management plans in realizing the zero-waste concept. However, this study found a 33% surge in waste generation per passenger compared to 2019. Similarly, the case study [32] on the recycling of e-waste in China and India elucidated the challenges that confront developing nations in their e-waste management endeavors. Their findings indicated that sociodemographic characteristics had no bearing on respondents' awareness or knowledge of e-waste, and there were no notable distinctions in their willingness to engage in e-waste management. Additionally, India had been processing both domestic and foreign e-waste in the informal sector for an extended period, lacking dedicated regulations for its disposal until more recently [32]. Nevertheless, the study failed to explore the factors underlying respondents' limited awareness or willingness to participate in e-waste management, restricting its practical applicability. The study suggested enhancing waste separation at the source to elevate waste diversion rates and zero-waste indexes. Despite meticulous methodology in characterizing waste from diverse sources, a study's findings were constrained to a single airport, and the reasons for low waste diversion rates remained unexamined, requiring further investigation [33]. The study acknowledges its own limitations, contributing to our understanding of e-waste management implementation. There is necessity of integrating informal e-waste workers and businesses into the formal sector for proper e-waste disposal [32].

Table 1. E-waste Management Challenges and Possible Solutions

Challenges	Possible Solutions
Lack of infrastructure	Invest in e-waste collection centers and recycling facilities.
Recycling facilities	Establish partnerships with international organizations for funding and technical assistance.
Informal recycling sector	Formalize and regulate the informal sector, providing training and support for safe recycling practices.
Limited public awareness	Conduct public awareness campaigns to educate individuals about proper e-waste disposal and recycling methods.
Inadequate policies and regulations	Develop comprehensive policies and regulations encompassing the entire lifecycle of electronic products.
Health and environmental hazards	Implement stricter health and safety standards for e-waste handling and disposal to minimize risks.
Lack of financial resources	Seek international cooperation and access financial resources for investment in e-waste management infrastructure.
Limited research and development	Encourage research and development in innovative technologies for efficient e-waste recycling and resource recovery.
Illegal export of e-waste	Strengthen enforcement of regulations and increase border controls to prevent the illegal export of e-waste.

A study has proposed the implementation of educational programs to enhance e-waste management in the region [34]. However, the study's confined scope impedes the generalization of findings to other regions or countries.

There is need of the integration of e-waste workers and businesses from the informal sector into a formal framework as a pivotal measure for proper e-waste disposal [32]. This case study enriches our understanding of India's situation and the challenges it confronts in managing e-waste. The case study provides invaluable insights into India's e-waste management challenges, highlighting the necessity for improved regulation and the incorporation of informal e-waste workers and businesses into the formal sector. Nevertheless, further research is indispensable to identify tailored strategies for integration and ascertain the relevance of the findings in diverse developing nations.

Numerous studies spanning various Asian countries and beyond have sought to address the universal challenge of e-waste. A study [35] found the inefficiency of solid waste management in Delta State, Nigeria, recommending the adoption of policy frameworks and best practices. Similarly, the study [36] in Addis Ababa, Ethiopia, highlights the value of public-private partnerships to enhance waste management and foster cooperation between formal and informal actors. Another pivotal facet of solid waste management is community involvement, who propose community

participation and clean-up programs as catalysts for enduring behavior change [37]. Additionally, education and economic factors influence waste generation and recycling rates [38]. A study on household waste classification in Beijing, emphasizing the role of social norms and government administration in promoting desirable behavior [39]. Likewise, e-waste management in Australia accentuates the requirement for local government intervention to promote sustainable e-waste management practices [40].

A study [36] about Addis Ababa's solid waste management system concludes that informal actors retain a substantial role in solid waste collection and recycling, despite modifications reducing their collaboration with formal actors. This underscores the significance of involving informal actors in waste management practices to heighten the system's overall efficiency. Nevertheless, the study's scope is confined to one city, making its generalizability to other regions or countries uncertain. The study [41] explores community members' comprehension of the roles played by government authorities and non-governmental organizations (NGOs) in Lahore's solid waste management.

The review of studies and case analyses reveals that e-waste pose critical environmental challenges, necessitating prompt action. Developing nations face obstacles such as inadequate regulations, limited infrastructure, and informal waste sectors. However, opportunities arise through collaborative efforts between

governments, NGOs, and private enterprises, leveraging public-private partnerships and education campaigns to enhance awareness and community engagement. Technological advancements also offer potential solutions. In essence, addressing these challenges can lead to more sustainable waste management practices that safeguard human well-being and foster environmental preservation.

4. Conclusion and Recommendations

The improper management of e-waste poses severe negative effects on the environment, economy, and human health. With the alarming rate of e-waste generation globally, it is crucial to address this growing concern. The environmental consequences of e-waste mismanagement, including soil and water contamination, pose risks to human health and the ecosystem. Moreover, in developing countries, the informal recycling sector has made the health and environmental risks worse, especially for disadvantaged communities. Addressing the challenges posed by e-waste requires effective solutions, accurate data, and comprehensive policies focusing on the 3Rs (Reduction, Reuse, and Recycle). Furthermore, the sustainable management of e-waste presents economic opportunities through the recovery of valuable metals. This review paper highlights the urgent need for proper regulations, infrastructure development, and public awareness to address the challenges of e-waste management in developing nations.

To address the challenges and environmental impacts associated with e-waste management in developing nations, it is crucial for governments to establish comprehensive policies and regulations encompassing the entire lifecycle of electronic products, while investing in infrastructure and capacity building. Public awareness campaigns and educational programs should be conducted to inform individuals about responsible e-waste disposal, and international cooperation is needed to access financial resources and technical expertise. There is urgent call for transitioning to a circular economy model, incorporating eco-design principles and extended producer responsibility, which can promote longevity, repairability, and recyclability of products. Additionally, research and development efforts should focus on innovative technologies for efficient e-waste recycling. By implementing these recommendations, developing nations can create sustainable e-waste management systems, mitigate environmental and health risks, and contribute to a circular economy.

References

- [1] M. Ikhlaiel, Environmental impacts and benefits of state-of-the-art technologies for E-waste management. *Waste Management*, 68 (2017) 458-474.
- [2] R. Widmer, H. Oswald-Krapf, D. Sinha-Khetriwal, M. Schnellmann, H. Böni, Global perspectives on e-waste. *Environmental Impact Assessment Review*, 25(5), (2005) 436–458. <https://doi.org/10.1016/j.eiar.2005.04.001>
- [3] B.N. Patel, B. Viswanathan, (2015). E Waste Problems -An Analysis. *International Journal of Advanced Research in Management and Social Sciences*, 4 (2015) 60-71.
- [4] X. Chi, M. Streicher-Porte, M. Wang, M.A. Reuter, Informal electronic waste recycling: A sector review with special focus on China. *Waste Management*, 31 (2011) 731–742. <https://doi.org/10.1016/j.wasman.2010.11.006>
- [5] B. Jaeger, A. Upadhyay, Understanding barriers to circular economy: cases from the manufacturing industry. *Journal of Enterprise Information Management*, 33(4), (2020) 729–745. <https://doi.org/10.1108/JEIM-02-2019-0047>
- [6] S. Ritzén, G.O. Sandström, Barriers to the Circular Economy – Integration of Perspectives and Domains. *Procedia CIRP*, 64 (2017) 7–12. <https://doi.org/10.1016/j.procir.2017.03.005>
- [7] N. Ferronato, A. Maalouf, A. Mertenat, A. Khanal, B. Copertaro, D. Yeo, H. Jalalipour, J. R. Veuthey, L. M.Ulloa-Murillo, M. Sebastian Thottathil, N. Aizat bin Shuaib, R. Caplin, V. Jaisree Mohandas, A review of plastic waste circular actions in seven developing countries to achieve sustainable development goals. *Waste Management & Research*, (2023). <https://doi.org/10.1177/0734242X231188664>
- [8] B.B. Khatri, (2019). E- Waste Management: An Emerging Challenge in Nepal. *NUTA Journal*, 6(1-2), 1-4. <https://doi.org/10.3126/nutaj.v6i1-2.23218>
- [9] J.A. Noor, (2019). Impacts of E-Waste in the Environment.
- [10] K. Parajuly, K.B. Thapa, C. Cimpan, H. Wenzel, Electronic waste and informal recycling in Kathmandu, Nepal: challenges and opportunities. *Journal of Material Cycles and Waste Management*, 20 (2018) 656–666. <https://doi.org/10.1007/s10163-017-0610-8>
- [11] P. Mishra, (2022) E-waste management in Nepal: Its challenges and way forward. Prashasan. <https://www.prashasan.com/2022/02/17/299228/>
- [12] Basel Convention. (2011) Overview. Basel Convention. <http://www.basel.int/Implementation/Ewaste/Overview/tabid/4063/Default.aspx>
- [13] R. Cayumil, R. Khanna, R. Rajarao, M. Ikram-ul-Haq, P.S. Mukherjee, V. Sahajwalla, (2016)

- Environmental Impact of Processing Electronic Waste – Key Issues and Challenges. InTech, <https://doi.org/10.5772/64139>
- [14] S. Sivaramanan, E-Waste Management, Disposal and Its Impacts on the Environment. *Journal of Environmental Science, Toxicology, and Food Technology*, 3(5), (2013) 531-537.
- [15] O. Osibanjo, I.C. Nnorom, The challenge of electronic waste (e-waste) management in developing countries. *Waste Management & Research*, 25(6), (2007) 489-501. <https://doi.org/10.1177/0734242X07082028>
- [16] U.K. Rizvee, E-Waste Management in India: Current Practices and Challenges. *International Journal for Research in Applied Science and Engineering Technology*, 8(7), (2020) 289-293.
- [17] A.F. Ahmad-Faisal Alias, M.B. Ishak, S.N.A.M. Zulkifli, R.A. Jalil, E-waste management: An emerging global crisis and the Malaysian scenario. *Renewable and Sustainable Energy Reviews*, 4(4), (2014) 444-457.
- [18] I. Otieno, E. Omwenga. E-Waste Management in Kenya: Challenges and Opportunities. *Journal of Emerging Trends in Computing and Information Sciences*, 6(12), (2015) 661-666.
- [19] S.K. Adanu, S.F. Gbedemah, M.K. Attah, (2020). Challenges of adopting sustainable technologies in e-waste management at Agbogbloshie, Ghana. *Heliyon open access*, 6, E04548. <https://doi.org/10.1016/j.heliyon.2020.e04548>
- [20] W.W. Ranasinghe, B.C.L. Athapattu, Challenges in E-waste management in Sri Lanka. In *Handbook of electronic waste management*, (2020) 283-322. <https://doi.org/10.1016/B978-0-12-817030-4.00011-5>
- [21] M.N. Islam, E-waste Management of Bangladesh. *International Journal of Innovative Human Ecology and Nature Studies*, 4(2), (2016) 1-12.
- [22] A. Maharjan, S. Khatri, B. Thapa, S. Pant, S. Pathak, S. Bhatta, K. Rijal, B. Bishwakarma, Solid waste management: Challenges and practices in the Nepalese context. *Himalayan Biodiversity*, 7 (2013) 71-76. <https://doi.org/10.3126/hebids.v7i1.40185>
- [23] M. Subedi, S. Pandey, A. Khanal, Integrated Solid Waste Management for the Circular Economy: Challenges and Opportunities for Nepal. *Journal of Multidisciplinary Research Advancements*, 1 (2023) 21–26. <https://doi.org/10.3126/jomra.v1i1.55100>
- [24] A. Khanal, Survey on usage of single use plastic bags in Nepal. In *IOP Conference Series: Earth and Environmental Science*. IOP Conference Series: Earth and Environmental Science, 1057 (2022) 012008. <https://doi.org/10.1088/1755-1315/1057/1/012008>
- [25] A. Khanal, (2023a). Forecasting municipal solid waste generation using linear regression analysis: A case of Kathmandu Metropolitan City, Nepal. *Multidisciplinary Science Journal*, 5 (2023) e2023019. <https://doi.org/10.31893/multiscience.2023019>
- [26] A. Khanal, S. Giri, P. Mainali, the Practices of At-Source Segregation of Household Solid Waste by the Youths in Nepal. *Journal of Environmental and Public Health*, (2023) 5044295. <https://doi.org/10.1155/2023/5044295>
- [27] A. Khanal, D.A. Sondhi, S. Giri, Use of personal protective equipment among waste workers of Sisdol landfill site of Nepal. *International Journal of Occupational Safety and Health*, 11(3), (2021) 158–164. <https://doi.org/10.3126/ijosh.v11i3.39768>
- [28] A. Khanal, COVID-19 related symptoms and vaccination usage among informal waste workers of Kathmandu, Nepal. *International Journal of Occupational Safety and Health*, 13(2), (2023) 155–162. <https://doi.org/10.3126/ijosh.v13i2.43929>
- [29] A. Khatiwada, R. Jariyaboon, K. Techato, E-Waste Management in Nepal: A Case Study Overcoming Challenges and Opportunities. *E-Prime - Advances in Electrical Engineering, Electronics and Energy*, 4 (2023) 100155. <https://doi.org/10.1016/j.prime.2023.100155>
- [30] D. Tiwari, N.G. Dhawan, E-waste management: An emerging challenge to manage and recover valuable resources. *International Journal of Environmental Research and Development*, 4(3), (2014) 253-260.
- [31] R.K. Henry, Z. Yongsheng, D. Jun, (2005). Country report Municipal solid waste management challenges in developing countries - Kenyan case study. *Waste Management*, 26 (2006) 92-100. <https://doi.org/10.1016/j.wasman.2005.03.007>
- [32] L. Lines, B. Garside, R. Sinha, I. Fedorenko, (2016) Clean and inclusive? Recycling e-waste in China and India. *International Institute for Environment and Development Report*.
- [33] İ. Ozbay, N.A. Gokceviz, towards zero-waste airports: a case study of Istanbul Airport. *Journal of Material Cycles and Waste Management*, 24, (2022) 134–142. <https://doi.org/10.1007/s10163-021-01308-2>
- [34] R.A. Miner, I.T. Rampedi, A.P. Ifegbesan, & R.L. Machete, (2020) Survey on Household Awareness and Willingness to Participate in E-Waste Management in Jos, Plateau State, Nigeria. *Sustainability*, 12(3), (2020) 1047. <https://doi.org/10.3390/su12031047>
- [35] O.C. Sylvester, A.A. Orowhigho, Study of Waste

Management in Solid Waste Collection and Evacuation in Delta State of Nigeria. International Journal of Research in Social Science and Humanities (IJRSS), 3(11), (2022) 27-33.

<https://doi.org/10.47505/IJRSS.2022.V3.11.3>

- [36] S. Khan, M.L. Loureiro, Formal and informal actors in Addis Ababa's solid waste management system. IDS Bulletin, 48(2), (2017) 53-70. <https://doi.org/10.19088/1968-2017.116>

- [37] I. Rangeti, B. Dzwairo, (2021) Guide for organizing a community clean-up campaign. IntechOpen. <https://doi.org/10.5772/intechopen.94515>

- [38] K. Shimamoto, Determining factors of waste management in Japan. Theoretical and Empirical Researches in Urban Management, 14(3), (2019) 62-76.

- [39] J. Cui, J. He, (2023) Study on the influence of social norms and public orientation on domestic waste classification behavior-taking Beijing's garbage classification as an example. Advances in Management & Applied Economics, 13(2), (2023) 47-63. <https://doi.org/10.47260/amae/1323>

- [40] G. Davis, S. Herat, Opportunities and constraints for developing a sustainable E-waste management system at local government level in Australia. National Library of Medical Science, 28(8), (2010) 705-713. <https://doi.org/10.1177/0734242X09343008>

- [41] S. Riaz, Z. Iqbal, G. Rasool, S. Parveen, S. Kalsoom, Knowledge of community members of Ali Raza Abad regarding the role of government authorities and non-government organization in solid waste management. Knowledge about solid waste management. NURSEARCHER (Journal of Nursing & Midwifery Sciences), 2(2), (2022) 12-16. <https://doi.org/10.54393/nrs.v2i02.12>

Has this article screened for similarity?

Yes

About the License

© The Author(s) 2024. The text of this article is open access and licensed under a Creative Commons Attribution 4.0 International License.

Acknowledgements

We are grateful to the Global Research Institute and Training Center for providing guidance to conduct this study.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

Data will be provided upon request.