Solid waste management in emerging economies: opportunities and challenges for reuse and recycling

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Editorial Note

Abstract

The increasing generation of solid waste, varying waste compositions, and inefficient waste recovery processes have limited the performance of traditional approaches. It is urgent to collect a virtual special issue (VSI) that consolidates research on efficient models and better treatment technologies to break up the current system limitations. Recently, Solid Waste Management (SWM) strategies that focus on reuse and recycling have revealed their current limitations or challenges. An awareness of the progress in addressing these limitations through the advancement in available technologies and the development of new systematic approaches for SWM are of increasing importance not just for advanced but more for emerging economies. Herein, this VSI aims to provide a review and collect important studies for SWM on reuse and recycling. The challenges and future opportunities in the application of SWM have been discussed to highlight the potential development in this VSI.

Keywords: solid waste management; reuse and recycling; emerging economy; waste treatment

Highlights

- Presented the content and key theoretical or methodology aspects in this SI
- Described SWM opportunities and challenges for reuse and recycling
- Presented the conceptual themes, methods, cases, and models
- Summarized practical policies, possible solutions, and implication

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1. Introduction

The environmental challenges facing human society have become increasingly concentrated due to rising living standards and rapid increase in population, which has resulted in regions with high population density. This has tremendously increased solid waste generation. In the face of these changes, the government must implement various solid waste management (SWM) practices; nevertheless, waste treatment infrastructure is continuously strained despite the efficient operation of waste minimization and resource recovery programs in emerging economies. The structural changes in community behavior of an economic system and solid waste disposal routines influence SWM execution (Maihami and Ghalehkhondabi, 2022; Tsai et al., 2021). Dissociations between economic growth, environmental pressures, and societal sustainability greatly impede SWM technology, which is then pressed to its limits, placing unexpected burdens on society (Araee et al., 2020).

More in-depth studies are needed to improve waste processes so that we can transition towards sustainability and create a society free from the risk of resource exhaustion. The opportunities and challenges for reuse and recycling should be preserved. However, rapid elaboration, cumulative discernment, and diverse social, political, environmental, and economic challenges result in very different technical and nontechnical barriers, making SWM a complex and uncertain topic (Bui et al., 2020; Fukuda, 2020).

Indeed, SWM also needs to understand the opportunities and challenges for reuse and recycling in solving key social and environmental problems. Highlighting these opportunities and challenges are a significant step towards improving waste management outcomes, developing technologies, and implementing alternative solutions. For instance, Bui et al. (2020) identified a set of barriers related to SWM practice and revealed that social acceptability, technical integration, and financial and economic problems are factors that affect SWM. The essential nature of technical perspectives, certain gaps related to aligning the technical barriers to reuse and recycling concept, and the nontechnical characteristics of sustainable perspectives to improve SWM can be addressed by examining the opportunities and challenges for reuse and recycling.

Understanding the SWM opportunities and challenges for reuse and recycling to enhance resource utilization and environmental protection in emerging countries are necessary (Chien et al., 2021; Maihami and Ghalehkhondabi, 2022). For example, Lin et al. (2022) employed artificial intelligence for hybrid optimization for reuse and recycle to promote cleaner semiconductor manufacturing. SWM resource utilization seeks to achieve both social and environmental sustainability by catalyzing innovations that underpin sustainable development. Improper disposal of solid waste creates unsanitary conditions, while these conditions in turn can lead to pollution of the environment. This VSI aims to further address the paradigms or challenges in emerging economies.

2. The virtual special issue research questions

This SI focuses on evolving SWM principles that explore the practices or policy recommendations for advancing the knowledge for resources optimization. The goal is to identify various SWM aspects that serve as either opportunities or challenges for reuse and recycling in the mining of resources from wastes. Contributors submitted excellent works ranging from the examination of case studies, to quantitative analytical models for specific situations, to broad-based case work. The contributions included various methodical approaches to answer the following SI objectives.

- To understand the roles of government and non-government organizations for SWM reuse and recycling in emerging economies
- To turn this SWM reuse and recycling concept into sustainable business models
- To propose innovative perspectives and technologies that will benefit SWM
- To understand behavioral patterns and build models which create opportunities for solid waste management and address current challenges in reuse and recycling.
- To collect sustainable paradigm cases in practice for SWM opportunities and challenges

3. Contributions of the virtual special issue

This section highlights the opportunities and challenges as a significant step towards improving waste management outcomes, developing technologies, and implementing alternative solutions. In particular, Sinha et al. (2022) conducted a comparative investigation of the long-run determinants of municipal solid waste (MSW) generation for the 10 best and least recycling economies in the OECD in terms of a set of technological, regulatory, and institutional regressors such as eco-innovation, environmental tax revenue, governance quality, an index of the structural transformation of the economy, and the capital-to-labor ratio. Liu et al. (2022) emphasized the need to understand the economic feasibilities of recycling technology options for blade waste management. A financial performance model for wind turbine blade end of life was developed and sensitivity analysis was performed to evaluate and compare the financial performance of all available end of life options.

SWM resource utilization seeks to achieve both social and environmental sustainability by catalyzing innovations that underpin sustainable development. Improper disposal of solid waste creates unsanitary conditions, and these conditions in turn can lead to pollution of the environment; on the other hand, how to turn this situation into opportunities needs to apply the “recycle and reuse” concepts. Lin et al. (2022) argued that attention should be paid on low-valued recyclables in integrated

SWM to identify opportunities for circular economy and carbon neutrality. It is only when high-resolution compositions of all waste components are considered that the maximum environmental savings can be precisely calculated and recycling-oriented strategies proposed. The small amount of packaging plastic recycling in residual municipal solid waste could contribute to great carbon sink.

Indeed, the opportunities and challenges for reuse and recycling in solving key social and environmental problems should also be investigated. Wang et al. (2022) posited a novel theoretical acceptance model for straw returning technology that integrated the Unified Theory of Acceptance and Use of Technology and Norm Activation Model. They systematically examined the factors affecting the acceptance of straw returning technology to fill gaps in today's agricultural waste recycling and reuse. Chiang and Lee (2022) decomposed the incinerator system into the waste treatment process and energy generation process via a two-stage network structure. They built a Russell multi-activity network data envelopment analysis model which considered the weak disposability of technology, and measured productivity changes over time and assessed the plants' returns-to-scale. Building models to further explore the solid waste solution for SWM.

Goh et al. (2022) presented the optimization of bioplastic production by creating a carbon-hydrogen-oxygen industrial symbiosis network to solve the sludge management and resources consumption problem; concurrently, the high production cost and limited process feasibility hinder the commercialization of the waste-derived polyhydroxyalkanoates synthesis process to explore material integration by implementing an industrial symbiosis network that enhances the sustainability of waste-derived polyhydroxyalkanoates production. Liu et al. (2022) aimed at minimizing the total costs of the sludge management system, mass constraints were considered in the model as well as the regulations on environmental emissions. A case study based on the conditions in Hong Kong was conducted to verify the feasibility of the proposed model. Four sludge-to energy technical routes were studied as the alternatives, covering incineration with landfill, incineration with cement production, gasification, and hydrothermal pyrolysis technology (HPT). Eleven sewage treatment services, four alternative sludge treatment facilities, and three landfill sites were considered.

In addition, Yu et al. (2022) proposed an optimum integrated strategy for recovery and carbon sink by simultaneously considering low-valued recyclables recycling and nonrecyclables reduction in anaerobically digested sludge management. A new mechanism underlying the observed substantial dewaterability improvements, i.e. acid-elutriation removes hydrophilic organic matter and leads to decreased repulsive force from hydration interaction energy. In sum, understanding the SWM opportunities and challenges for reuse and recycling to enhance the resource utilization and environmental protection in emerging countries is critical and remains a challenge for most of emerging countries

4. Findings of the virtual special issue

- Waste-derived synthesis process is restricted to the pilot scale with high investment costs and poor material recovery serving as the key barriers that hinder the development of the polyhydroxyalkanoates synthesis process on a larger industrial scale. An alternative pathway is to apply industrial ecology and circular economy concepts to enhance the sustainability of the bioplastic industry by cooperating with other biorefinery plants that result in the formation of a promising industrial symbiosis.
- Results obtained from the proposed financial performance model for wind turbine blade end-of-life option identified that mechanical recycling and fluidized-bed recycling are the optimal options of the ready to-go technologies, and chemical recycling is the optimal option for technologies currently available only at lab scale (Liu et al., 2022a).
- An optimization model was used for sludge valorization management to solve the supply chain design problem. The costs of centralized sludge treatment in Hongkong were lower than the total costs of several dispersed sludge treatment facilities that received and treated sludge. A suitable and cost-effective sludge-to-energy technology can contribute to the reduction on the total costs (Wang et al., 2022).
- Agricultural waste recycling and reuse technology performance expectancy affects rural households' intention to accept straw returning technology. Rural households who have used the straw returning technology before would have a more precise understanding of operations compared to those people without any experience. The impact of effort expectancy on behavioral intention reduces with increasing user experience (Liu et al., 2022b).
- The dynamic elasticity-based interactive effects stress that environmental tax and governance quality enhance the environmental impact of eco-innovation, whereas structural transformation of the economy and capital-to-labor ratio lower the size of this effect, with a much lower magnitude in the bottom-10 recycling OECD economies. Associated policy recommendations are aimed at aiding the design of adequate waste management policies
- The waste treatment process itself is the major cause of inefficiency, indicating that incinerator operators should reallocate input resources. In addition, conducting routine eco-efficiency evaluations of SWM in incinerators should be

validated. Minor productivity changes and most plants maintain constant returns-to scale and some incinerators in Southern Taiwan having inefficient scale sizes should be rescaled to improve productivity (Chiang and Lee, 2022).

- Recyclable plastic and packaging only accounted for 7.7% and 2.0% in residual municipal solid waste compared with incineration, recycling low-valued recyclables. Further restricting non-recyclables decreased greenhouse gas. The low-valued recyclable packaging in residual municipal solid waste should be transformed from incineration to recycling and non-recyclables should be reduced Towards circular economy and carbon neutrality.

5. Conclusion

This VSI provides the opportunities and challenges for reuse and recycling and its application in MSW cases. However, this VSI relates the studies to MSW in regional studies, policy, and industry cases. In summary, potential research directions include:

- There is great potential to conduct more case studies in solving the MSW issues from the perspectives of optimization models, wind turbines, and pollutants reduction as for the final treatment and recovery processes. For instance, wind turbines are a clean technology if only the operational stage of their life cycle is considered. However, the manufacture and end-of-life stages require large amounts of energy and release significant pollutions including greenhouse gases.
- It is challenging to propose an acceptance model that considers the characteristics of straw returning technology in terms of protecting the environment on the acceptance of straw returning technology for rural households in the northeastern regions of China.
- A three-layer optimization model based on mixed-integer programming was proposed to solve the sustainable supply chain design problem to realize effective sludge treatment as well as energy recovery simultaneously for sustainable urban sludge management.
- The incinerator supports the energy recovery from waste through the waste treatment process and energy conversion process. However, the incinerator may also emit the air pollutants when they generate the desirable output (e.g. electricity). Although the incinerators in many countries are already under strict control of dioxin emission and may meet a stringent limit of the local regulation, there is still room to reduce the emissions (e.g. ashes, dioxin, CO_2, SOx) and improve the productivity

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