Integrated Solid Waste Management for the Circular Economy: Challenges and Opportunities for Nepal

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Abstract: The article emphasizes the importance of implementing Integrated Solid Waste Management (ISWM) and circular economy principles for effective solid waste management, which prioritizes waste prevention, recycling, and environmentally sound disposal practices. The article provides an overview of how ISWM and circular economy principles have been successfully implemented in several countries worldwide and emphasizes the need for their adoption in Nepal, where proper solid waste management systems are often inadequate or non-existent. The article provides insights into the challenges and opportunities for Nepal in adopting such practices and recommends practical methods for improving waste management in the country. The researchers conducted a comprehensive search of the available literature on the topic of ISWM and circular economy in Nepal to draw conclusions and recommendations for the future direction of solid waste management in Nepal. Although, there is the formulation of new laws and policies related to solid waste management in Nepal, the country lacks active implementation of the laws by both governments and waste management companies.

Keywords: *Circular economy, ISWM, Nepal, Solid waste, Waste management*

Conflicts of interest: None
Supporting agencies: None

Accepted 15.4.2023

Cite This Article: Subedi, M., Pandey, S., & Khanal, A. (2023). Integrated Solid Waste Management for the Circular Economy: Challenges and Opportunities for Nepal. *Journal of Multidisciplinary Research Advancements*, 1(1), 21-26.

1. Introduction

The global population is projected to reach 8 billion by 2025, which will lead to an increase in product consumption and solid waste generation (Arsalan et al., 2020). Of the 7-9 billion tonnes of solid waste produced annually, 2 billion tonnes are attributed to municipal solid waste (MSW) (Wilson and Velis, 2015). The health and environmental impacts of MSW disposal depend on the waste types and management techniques used (Eriksson et al., 2005). Plastic waste is a major concern as it can persist in the environment for a long time and can be consumed by organisms, potentially causing harm to humans and other animals in the food chain (Thompson et al., 2009; Ghadge, Khare, Bhosale, Giri, & Jadhav, 2022). Additionally, fugitive emissions throughout the solid waste management process contribute to 3%-4% of greenhouse gas emissions (Monni et al., 2006). The continuous increase in solid waste generation and the use of landfills can have adverse effects on public health, the environment, and the climate.

Integrated solid waste management (ISWM) and the circular economy are two approaches that prioritize waste prevention, recycling, and environmentally sound disposal practices (Sridevi et al., 2012; Giri, 2021; SWANA, 2003). The principles of the circular economy include eliminating waste and pollution, circulating products and materials, and regenerating nature (Mohamad Santori et al., 2021). In ISWM systems, final disposal at sanitary landfills is given the lowest priority. According to the UNEP (2015), ISWM is a critical strategy for achieving sustainable waste management. The UNEP advocates for the implementation of ISWM in developing countries, where waste management systems are often inadequate or non-existent. In a report titled "Global Waste Management Outlook," the UNEP stated that ISWM can help address the challenges associated with the growing amount of waste generated worldwide, including environmental pollution and public health concerns.

ISWM has been successfully implemented in several countries worldwide, including Japan, Denmark, and Germany (Wilson et al., 2015). These countries have developed innovative waste management systems that prioritize waste reduction, segregation, and recycling. For instance, in Japan, waste segregation is mandatory, and citizens are required to separate their waste into various categories, including plastic, paper, and organic waste (Zaman et al., 2017). The country has also developed advanced technologies for processing waste, such as incineration facilities that generate energy from waste. In Denmark, waste management is based on the "waste hierarchy," which prioritizes waste prevention, reduction, and recycling over disposal (European Environment Agency, 2018). The country has implemented several waste reduction and recycling programs, including a deposit system for beverage containers and a food waste collection program. In Germany, the "Dual System" of waste management, which involves the separation and collection of recyclable waste by private companies, has been successful in increasing recycling rates (European Environment Agency, 2018). The country has also implemented the "Green Dot" system, which requires manufacturers to take responsibility for the waste generated by their products.

Urbanization in Nepal has led to an increase in solid waste generation, and the linear waste management system currently in place involves collecting waste from households and dumping it in landfills (Bharadwaj et al., 2020). There is lack of source segregation in Nepal (Khanal, Giri and Mainlai, 2023). Many cities in Nepal, including Kathmandu, Lalitpur, Biratnagar, and Pokhara, struggle with effective solid waste management due to their high population density (ADB, 2013; Amrit Maharjan et al., 2019). The waste generation rate in Nepali municipalities is estimated to be 3023 tons per day, with organic waste accounting for 60% and recyclable materials like plastic, paper, and metal accounting for 25% (ADB, 2013). Most municipalities in Nepal follow similar waste management strategies, which involve collection, transportation, and landfill disposal (Mohan Krishna Maharjan et al., 2019). The capital city of Nepal, Kathmandu Metropolitan City, generates the highest amount of solid waste in the country, with the current generation rate of 766 tons per day expected to reach 1259 tons per day by 2035 (Khanal, 2023).

Several studies found that Nepal did not adopt ISWM and circular economy principles in waste management. Thus, the current study aimed to recommend helpful and adaptable methods for waste management in Nepal, with the objective of promoting sustainable development goals (SDGs) and addressing the challenges posed by increasing solid waste generation in the country. The study highlights the importance of adopting ISWM and circular economy principles for effective solid waste management in Nepal. The study also provides insights into the challenges and opportunities for Nepal in adopting such practices and recommends practical methods for improving waste management in the country.

2. Materials and methods

This review paper was conducted by gathering secondary literature from various online databases, including Springer, Google Scholar, ScienceDirect, and ResearchGate. The search for relevant literature was conducted using specific phrases such as 'Solid waste management', 'Integrated solid waste management', 'Circular economy', 'Sustainable Development Goal', 'SDGs waste management', and 'Waste management Nepal'. These phrases were chosen to gather literature relevant to the integrated waste management and circularity status.

The primary objectives of the study were to determine the current status of integrated solid waste management in Nepal and to identify the current challenges and opportunities for achieving Sustainable Development Goals (SDGs) in this area. The study aimed to examine the available literature on integrated solid waste management and to draw conclusions and recommendations for the future direction of solid waste management in Nepal. To carry out this review, the researchers conducted a comprehensive search of the available literature on the topic of integrated solid waste management and circular economy in Nepal. The researchers analyzed and synthesized the findings from the relevant literature, including research articles, reports, and policy documents. The review paper synthesized the available literature on the integrated solid waste management approach, which includes waste reduction, reuse, recycling, composting, and energy recovery.

4. Results and discussion

The circular economy is a production and consumption model that emphasizes on sharing, reusing, repairing, and recycling resources to reduce waste and pollution. This model is based on three fundamental principles: eliminating waste and pollution, circulating products and materials, and regenerating nature (Reuter et al., 2019). The circular economy is an economic system that aims to minimize waste and contamination throughout the entire lifecycle of materials, from extraction to disposal, while ensuring the sustainability of associated ecosystems (Nobre et al., 2021). This system strives towards reducing the negative impact of waste on climate change, biodiversity loss, and pollution through its designed principles.

Waste management is the process of managing waste from its generation to its final disposal by collecting, transporting, and disposing of waste while monitoring and regulating the process and the laws associated with it. Waste can be in solid, liquid, or gaseous form, and each form has different methods of disposal and management. The waste hierarchy is a term

that groups waste management strategies into categories based on their ability to minimize waste. It includes the "3 Rs" - Reduce, Reuse, and Recycle - and serves as a guide for policymakers to limit waste generation (Albert & Raleigh, 2011). According to the United Nations Environment Programme (2013), the waste hierarchy is represented as a pyramid to emphasize the importance of policies that promote waste reduction and limit waste generation.

The Sustainable Development Goals (SDGs) are a set of 17 interconnected global goals established by the United Nations in 2015. These goals aim to eliminate poverty, hunger, discrimination, and other pressing global issues and promote peace and prosperity on the planet by 2030. The 17 SDGs include No Poverty, Zero Hunger, Good Health and Well-being, Quality Education, Gender Equality, Clean Water and Sanitation, Affordable and Clean Energy, Decent Work and Economic Growth, Industry, Innovation and Infrastructure, Reduced Inequalities, Sustainable Cities and Communities, Responsible Consumption and Production, Climate Action, Life Below Water, Life On Land, Peace, Justice and Strong Institutions, and Partnerships for the Goals.

In summary, the circular economy emphasizes the importance of reducing waste and pollution through three fundamental principles, namely eliminating waste and pollution, circulating products and materials, and regenerating nature. Waste management involves the process of collecting, transporting, and disposing of waste while monitoring and regulating the process and the laws associated with it. The waste hierarchy categorizes waste management strategies based on their ability to minimize waste, and the SDGs aim to eliminate global issues and promote peace and prosperity on the planet.

Table 1: SDGs goals related to the solid waste and circular economy

SDG Goal Number and title	**Target**
11: Make cities and human settlements inclusive, safe, resilient, and sustainable	Target 11.1 By 2030, ensure access for all to adequate, safe, and affordable housing and basic services and upgrade slums. Target 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management in all countries. Target 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.	Target 8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead.
10: Reduce inequality within and among countries.	Target 10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 percent of the population at a rate higher than the national average. Target 10.2 By 2030, empower and promote the social, economic, and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, or economic status. Target 10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies, and practices and promoting appropriate legislation, policies, and action in this regard.
12: Ensure Sustainable consumption and production patterns	Target 12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries. 12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses. 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycles, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment. 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.

ISWM has a significant impact on public health and safety, as well as achieving sustainability by reducing landfill sites by half (Siti Nadzirah et al., 2013). It can prevent harm to ecosystems, human health, and loss of biodiversity, including air, water, and soil pollution, along with negative social and economic consequences (Maryam Mohammadi et al., 2019). By adopting ISWM with Waste to Energy (WTE) technologies and recycling based on 3R (reduce, reuse, recycle)

principles, potential energy of 1.72 Twh/year can be generated, making revenue for waste management and protecting the ocean and rivers (Sadef, Y. et al., 2016). Implementing an ISWM system can decrease or stop the disposal of organic waste at landfills, preventing CH4 emissions that would result from the breakdown of organic waste in landfills (Menikpura et al., 2013). In developing nations, more than 70% of municipal solid trash is biodegradable, contributing significantly to GHG (greenhouse gas) emissions in large cities. However, implementing ISWM principles can reduce these emissions (Ramachandra et al., 2018).

One of the significant challenges facing ISWM is inadequate financing. Effective waste management requires significant investments in infrastructure, equipment, and personnel, which many governments and municipalities may not have the resources to provide. As a result, waste management services may be inadequate or non-existent in some areas, leading to the proliferation of uncontrolled dumpsites and illegal waste disposal practices (UNEP, 2015). To overcome this challenge, governments and municipalities need to prioritize waste management and allocate sufficient resources to support ISWM initiatives.

Another challenge of ISWM is the lack of institutional capacity. Many developing countries lack the institutional capacity to implement ISWM effectively. This includes the lack of trained personnel, appropriate equipment, and policies and regulations to guide waste management practices (Jenks, 2013). In addition, there may be insufficient coordination and communication between different stakeholders involved in waste management, including government agencies, private sector actors, and civil society organizations. To address this challenge, governments and municipalities need to strengthen their institutional capacity by investing in training and education programs for personnel, developing appropriate policies and regulations, and promoting stakeholder participation and engagement.

Public participation is another critical challenge facing ISWM. Effective waste management requires the participation and cooperation of the public, who are responsible for generating waste. However, in many cases, there is limited public awareness and understanding of waste management issues, leading to poor waste management practices and a lack of support for ISWM initiatives (UNEP, 2015). To address this challenge, governments and municipalities need to invest in public education and awareness campaigns to promote responsible waste management practices and encourage public participation in waste management activities.

Despite these challenges, ISWM presents several opportunities for resource recovery, job creation, and environmental protection. One of the significant opportunities of ISWM is the potential for resource recovery through recycling and composting. Recycling and composting can help recover valuable resources from waste streams, reduce the need for virgin materials, and create jobs in the recycling and composting industries (UNEP, 2015). In addition, ISWM can help reduce greenhouse gas emissions and mitigate climate change by reducing the amount of waste sent to landfills and promoting the use of renewable energy from waste (Kaza et al., 2018).

Another opportunity of ISWM is job creation. Effective waste management can create job opportunities in various sectors, including waste collection, transportation, sorting, recycling, and composting. In addition, waste management can also generate income for informal waste pickers and recyclers, who often work in unsafe and unhealthy conditions (Jenks, 2013; Khanal, Sondhi and Giri, 2021; Khanal, 2021). By formalizing the waste management sector and providing training and support to workers, ISWM can help create decent work and promote social and economic development.

Although solid waste management is a major problem in every city and municipality in Nepal, implementing ISWM is challenging due to obstacles such as lack of sector funding and technical capacity, lack of high-level and automated machines for waste treatment, and lack of initial investment for the construction of a large-scale anaerobic digestion plant and advanced incineration (Zubin Shrestha, 2018; Maharjan and Lohani, 2019; Pathak et al., 2021). Urbanization, development, and rapid expansion in Nepal are leading to more air pollution, freshwater poverty, toxic rivers, water table depletion, and soil erosion. The country needs to transition to the waste management sector, aligning with the Circular Economy approach (Perrin, 2021).

According to Acharya (2017), managing solid waste is a challenging process, from collection to resource recovery and final disposal. Several projects worldwide, such as the SWITCH Africa Green program (Burkina Faso, Ghana, Kenya, Mauritius, South Africa, Uganda), The Energy Transition Law for Green Growth (France, 2015), and Swachha Bharat Mission-Urban (SBM-U), Swaccha Survekshan, Swachhata Hi Sewa Campaign, Compost Banao, Compost Apnao Campaign (India, 2016), have contributed to waste minimization, reduced pollution, better health and safety, monetary gains, job creation, and improved well-being. However, in Nepal, there are policy implementation deficiencies marked by the gaps between legal and institutional order and what is in practice. Although new laws and policies related to solid waste management have been formulated, the country lacks active implementation of such laws and policies by both governments and citizens. Furthermore, the lack of involvement of citizens in the strategy and poor decision-making processes are also included in the country's poor waste management system (Maharjan et al., 2019).

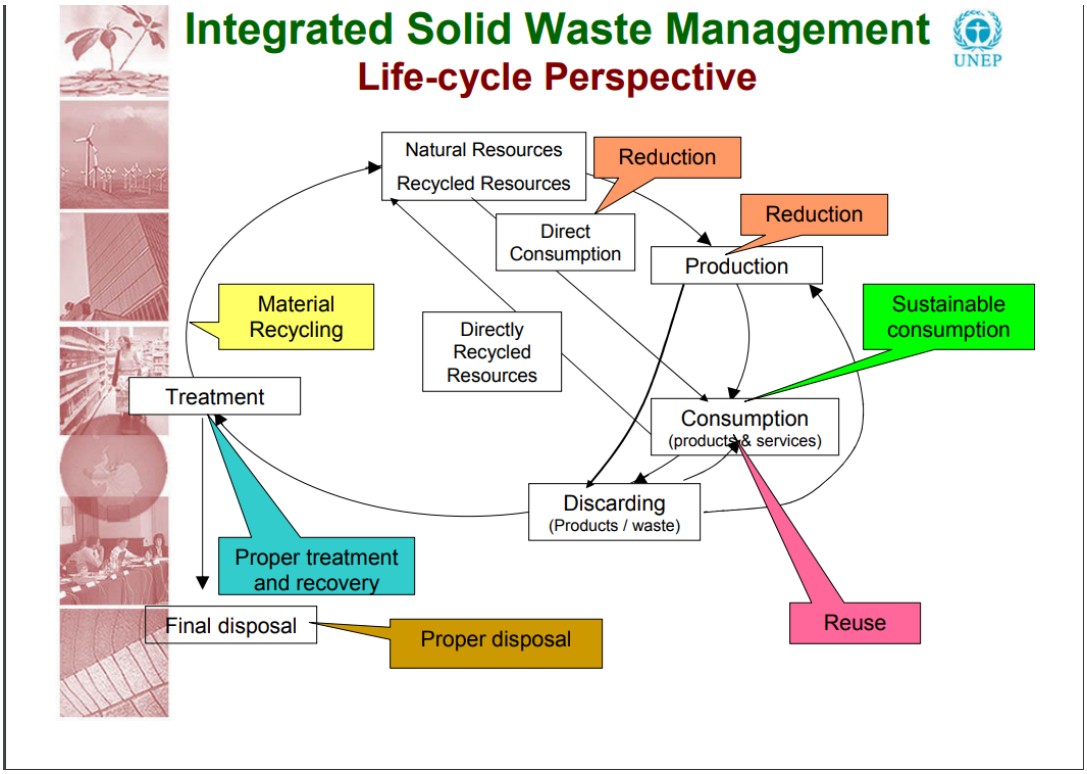
Nepal's waste management system is mainly informal, with a large proportion of the waste being collected and disposed of by informal waste pickers and small-scale operators. The waste collection infrastructure is inadequate, particularly in rural areas, and many communities do not have access to basic waste collection services. As a result, a significant amount of waste in Nepal is deposited in uncontrolled dumpsites, which pose serious risks to public health and the environment (Paudel et al., 2018).

To address these challenges, the Nepalese government has implemented several policies and initiatives to promote ISWM. For instance, in 2011, the government introduced the Solid Waste Management Act, which provides a legal

framework for waste management in the country. The act encourages the participation of local communities and private sector actors in waste management activities, and promotes waste reduction, reuse, recycling, and safe disposal of waste. Furthermore, the government has launched various programs to improve waste management infrastructure and services in the country. One such initiative is the Solid Waste Management and Resource Mobilization Center, which was founded in Kathmandu in 1999. The center provides technical assistance and training to municipalities and other stakeholders involved in waste management, and supports waste reduction and recycling programs.

Despite these initiatives, Nepal still faces significant challenges in implementing ISWM. A primary challenge is the lack of institutional capacity and technical expertise in waste management. Many municipalities lack the resources and expertise to develop and implement effective waste management strategies, and there is a shortage of trained personnel in the waste management sector (Paudel et al., 2018). To overcome this challenge, the government needs to invest in training and education programs for waste management personnel, and strengthen institutional capacity at the local and national levels.

Another challenge is the insufficient infrastructure for waste management. Many communities lack basic waste collection services, and there is a shortage of appropriate waste treatment and disposal facilities in the country. Furthermore, the informal waste management system is often unregulated and unsafe, posing risks to public health and the environment (Shrestha & Khanal, 2015). To address this challenge, the government needs to invest in waste management infrastructure, such as collection vehicles, transfer stations, and sanitary landfills, and promote public-private partnerships in the waste management sector.



Source: UNEP, DTIE, IETC

5. Conclusion

Integrated solid waste management (ISWM) includes an effective system of waste collection, transportation, recovery, and environmentally friendly disposal of waste. ISWM involves a series of complementary actions to reduce and recover value from wastes, and to dispose of them in an environmentally sound manner with the final disposal of wastes at sanitary landfills given the lowest priority. ISWM can equally important to prevent harm to ecosystems, damage to human health, and loss of biodiversity including air, water, and soil pollution along with negative social and economic consequences. The waste hierarchy serves as a guide for policymakers to limit waste generation and promote waste reduction. The SDGs related to solid waste and circular economy emphasize the importance of enhancing sustainable urbanization, reducing environmental impact, promoting resource efficiency, reducing inequality, and ensuring sustainable consumption and production patterns. Nepal's waste management system is predominantly informal, with inadequate waste collection infrastructure, resulting in uncontrolled dumpsites that threaten public health and the environment. The Nepalese government has launched various initiatives to promote ISWM, including the Solid Waste Management Act and the Solid Waste Management and Resource Mobilization Center. However, the country still faces

significant challenges in implementing ISWM, such as the lack of institutional capacity and technical expertise in waste management and the inadequate infrastructure for waste management.

Acknowledgements

The authors thank the Global Research Institute and Training Center (GRIT) to support this study.

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