Solid Waste Collection and Segregation in Kathmandu

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Abstract

This study examines the impact of solid waste collection and segregation in Kathmandu. Solid waste management is the dependable variable. The independent variables are municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges. The primary source of data is used to assess the opinions of the respondents regarding the impact of solid waste collection and segregation in Kathmandu. The study is based on primary data of 125 respondents. To achieve the purpose of the study, structured questionnaire is prepared. The correlation coefficients and regression models are estimated to test the different factors affecting solid waste management in Kathmandu.

The result shows that municipal solid waste management has a positive impact on solid waste management. It indicates that increase in municipal solid waste management practices leads to increase in solid waste management. Similarly, waste segregation has a positive impact on solid waste management. It means that effective waste segregation leads to increase in solid waste management. Likewise, recycling program has a positive impact on the solid waste management. It shows that efficient management of recycling programs leads to increase in solid waste management. Further, household participation practices has a positive impact on solid waste management in Nepal. It indicates that increase in household participation practices leads to increase in solid waste management. Moreover, environmental challenges has a positive impact on solid waste management. It indicates that increase in environmental challenges practices leads to increase in solid waste management.

Keywords: solid waste management, municipal solid waste management, waste segregation, recycling programs, household participation, environmental challenge

1. Introduction

Solid waste collection and segregation refer to the systematic processes of gathering and sorting waste into different categories to facilitate its proper disposal, recycling, and treatment. Both are essential for effective waste management, helping reduce environmental impact, improve recycling rates, and protect public health. Urbanization and population growth have significantly increased the quantity and complexity of municipal solid waste (Guerrero *et al*., 2013). Segregation at the source involves separating waste into categories such as organic, recyclable, and hazardous materials. This practice enhances recycling efficiency and reduces the burden on landfills. A study highlighted that effective waste segregation is pivotal for realizing reuse, recycling, and recovery, thereby contributing to sustainable waste management, (Kassim and Ali, 2006). Household participation in waste segregation is influenced by various factors, including awareness, convenience, and socioeconomic status. Research in Ethiopia revealed that 50.3% of households practiced waste segregation, with higher rates observed among those with better access to information and waste collection services (Debesay *et al.,* 2021). The integration of informal waste collectors into formal waste management systems has been identified as a strategy to improve waste segregation and collection efficiency. In many developing countries, informal waste workers contribute significantly to recycling efforts. Recognizing and formalizing their roles can enhance overall waste management outcomes (Wilson *et al.,* 2006). Pay-as-you-throw schemes, where residents are charged based on the amount of non-recyclable waste they produce, have been successful in reducing waste volumes and increasing recycling rates in various municipalities

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(Dijkgraaf and Gradus, 2004).

Malik *et al*. (2015) analyzed that the community participation on solid waste segregation through recycling programmes in Putrajaya. The study explored that the correlation between community participation in recycling programs and both community attitudes and knowledge regarding solid waste segregation. Similarly, Wu *et al.* (2023) studied that the use of smart bins and mobile applications improved segregation practices by 35%. The study found that these technologies were especially effective in urban areas with tech-savvy populations. Likewise, Gupta and Sharma (2021) analyzed that the economic incentives for promoting household waste segregation. The study found that the financial incentives such as discounts on utility bills or cash rewards increased segregation rates by 30%, especially in low-income neighborhoods. Further, Patel *et al.* (2020) investigated that the behavioral barriers to household solid waste segregation in urban India. The study revealed that the lack of environmental awareness and motivation were identified as significant barriers. Households with access to educational campaigns showed a 50% increase in compliance. Moreover, Bai and Chen (2020) analyzed health implications of solid waste segregation at the household level. The study demonstrated that the proper waste segregation led to a 30% reduction in waste-related illnesses in participating communities, showcasing its importance for public health. However, Lave and Wang (2019) evaluated that the household participation in recycling: A study of behavioral factors. The study found that household participation in recycling programs is significantly influenced by socio-economic factors such as income, education, and awareness. The study also highlighted that higher levels of environmental education and community-based incentives positively impacted recycling participation rates. Furthermore, Chen and Zhang (2021) examined that the influence of household waste segregation on community recycling success. The study showed that when households actively segregate waste, recycling programs tend to perform better, leading to higher recycling rates and lower contamination of recyclable materials. Additionally, Maloney and Henson (2021) analyzed that the behavioral economics of household participation in waste sorting. The study found that small financial incentives and public recognition increased household participation rates in waste segregation programs. Social norms and peer pressure also played significant roles. However, Hasan and Ali (2019) evaluated that the effectiveness of municipal solid waste management systems in urban areas. The study argued that that the most successful systems combined efficient collection methods, widespread recycling programs, and public participation. The study also found that urban areas with higher levels of community involvement and government support achieved better waste diversion rates.

Singh and Mehta (2020) assessed that the understanding household barriers to participation in waste segregation programs. The study highlighted that the several barriers to household participation in waste segregation programs, including a lack of understanding about the benefits, inadequate facilities, and insufficient time. The study also concluded that overcoming these barriers through education and better infrastructure is key to improving participation. Similarly, Williams and Davies (2021) studied that the household waste segregation and its impact on waste reduction efforts. The study found that household participation in waste segregation significantly reduces the total volume of waste that needs to be landfilled. The study also showed that the households that segregate their waste are more likely to recycle and compost, contributing to a decrease in overall waste generation. Likewise, Liu and Zhang (2020) explored that the household participation in waste sorting and the role of environmental education. The study argued that the households that received targeted

environmental education were more likely to engage in waste segregation, demonstrating the importance of awareness-raising campaigns. Further, Gupta and Kumar (2019) studied that the municipal solid waste management and sustainability. The study found that the integration of sustainability into waste management strategies leads to improved waste diversion, reduced landfilling, and enhanced recycling efforts. Moreover, Alavi and Ramachandra (2020) investigated that the municipal solid waste management in developing countries. The study focused on the challenges of managing municipal solid waste in developing countries. The study found that these countries often struggle with inadequate infrastructure, limited funding, and insufficient public participation, leading to inefficient waste management systems. The study also emphasized the need for local government involvement, community engagement, and international support to address these challenges. Additionally, Shah and Kumar (2020) analyzed that the integrated municipal solid waste management system: A case study of South Asian cities. The study found that integrating various waste management methods (e.g., recycling, composting, and energy recovery) significantly improved waste management outcomes. The study also concluded that a holistic approach involving public participation, policy enforcement, and local initiatives was essential for effective waste management. Furthermore, Singh and Mehta (2021) explored that the role of technology in municipal solid waste management: Innovations and best practices. The study found that the adoption of these technologies improves operational efficiency, reduces environmental impact, and provides cost-effective solutions to waste management challenges.

Zhou and Zhang (2019) assessed that the environmental impacts of municipal solid waste management systems. The study revealed that landfilling and incineration contribute to significant environmental pollution, whereas recycling, composting, and waste-to-energy solutions offer more sustainable alternatives that reduce carbon emissions and waste volumes. Similarly, Lee and Park (2020) examined that the financial sustainability of municipal solid waste management systems. The study highlighted that the cost-effective waste management requires not only adequate funding but also cost recovery mechanisms such as user fees, recycling revenues, and government subsidies. The study also emphasized the importance of creating financially sustainable MSWM systems to ensure long-term viability. Likewise, Kumar and Awasthi (2021) studied that the public participation in municipal solid waste management: Challenges and opportunities. The study found that public participation is essential for the success of MSWM systems, as it helps increase recycling rates, reduce waste generation, and improve the overall effectiveness of waste management strategies. The study also highlighted that the barriers to participation, including lack of awareness, infrastructure, and government support. Further, Martinez-Conesa and Martinez (2020) analyzed that the effect of policy frameworks on municipal solid waste management. The study found that robust regulatory frameworks that promote waste reduction, recycling, and resource recovery are critical for improving MSWM outcomes. The study also concluded that successful waste management is strongly linked to political will and regulatory enforcement. However, Wang and Li (2021) analyzed that the urban municipal solid waste management and climate change. The study found that cities with integrated waste management policies that include reduction, recycling, and composting initiatives were more successful in reducing methane emissions from landfills, contributing to climate change mitigation. Moreover, Pires and Martins (2019) examined that the impact of economic factors on municipal solid waste management systems. The study revealed that wealthier cities tend to have more developed waste management systems due to better infrastructure, higher public investment, and improved technology. Furthermore, Verma and Bhardwaj (2019) found that proper waste segregation at the source

is essential to the efficiency of urban waste management systems. Additionally, Kapoor and Patel (2020 found that higher levels of environmental awareness, income, and education were positively correlated with waste segregation practices.

In the context of Nepal, Khadka *et al*. (2020) analyzed that the factors influencing municipal solid waste generation and composition in Kathmandu Metropolitan City, Nepal. The study estimated that the household solid waste generation and its composition in Kathmandu Metropolitan City (KMC) and assessed that the socioeconomic factors influencing waste generation. Similarly, Subba (2021) investigated that the practices of waste management in health care facilities in Nepal's Biratnagar metropolitan city. The study showed that the current state of healthcare waste management in Biratnagar, Nepal, and identify strategies for improving waste disposal practices. Likewise, Dhakal (2020) investigated that the waste management scheme and way forward for during and post COVID-19. The study found that the safety of waste workers, public perception, recycling opportunities, and the potential for extracting oil from plastic waste were the significant factors which affects the waste management practices. Further, Gurung and Oh (2012) examined Municipal solid waste management: Challenges and opportunities in Nepal. The study found that the feasibility of converting municipal solid waste in Nepal into biogas energy as a sustainable solution to address the country's energy crisis and mitigate environmental pollution. A comprehensive review of existing research on waste-to-energy technologies, specifically biogas production from municipal solid waste, with a focus on the Nepalese context.

The above discussion shows that the empirical evidences vary greatly across the studies concerning the solid waste collection and segregation in Kathmandu. Though there are above mentioned empirical evidences in the context of other countries and in Nepal, no such findings using more recent data exist in the context of Nepal. Therefore, in order to support one view or the other, this study has been conducted.

The main objective of the study is to analyze the factors that affect Solid Waste collection and segregation in Kathmandu. Specifically, it examines the effect of municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges on solid waste management in Kathmandu.

The remainder of this study is organized as follows. Section two describes the sample, data and methodology. Section three presents the empirical results and the final section draws the conclusion.

2. Methodological aspects

The study is based on the primary sources of data which were gathered from 125 respondents in in Kathmandu. For primary data a structured questionnaire was used. This study contains a sample of Kathmandu, Nepal whose respective data are collected from a total of 125 respondents. The respondents' views were collected on municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges and solid waste collection. This study is based on descriptive as well as casual comparative research designs.

The model

The model used in this study assumes that solid waste management on various factors in Kathmandu. The dependent variable selected for the study is solid waste management. Similarly, the independent variables are municipal solid waste management, waste

segregation, recycling programs, household participation and environmental challenges. Therefore, the model estimated in this study is stated as follows:

$SWM = \beta 0 + \beta 1\ RP + \beta 2\ HP + \beta 3\ MSWM + \beta 4\ WS + \beta 5\ EC + e$

Where

SWM = Solid Waste Management

RP = Recycling Programs

HP = Household Participation

MSWM = Municipal solid waste Management

WS = Waste Segregation

EC = Environmental Challenges

Solid waste management was measured using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Effective solid waste management is essential for maintaining public health and minimizing environmental pollution in urban areas", "The implementation of integrated waste management systems, which include reduction, reuse, recycling, and safe disposal, is crucial for sustainable waste practices" and so on. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.913$).

Municipal solid waste management was measured using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Effective solid waste management is essential for maintaining public health and minimizing environmental pollution in urban areas", "Sustainable solid waste management requires collaboration between government, businesses, and communities" and so on. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.888$).

Waste segregation were measure using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Waste segregation at the source is vital for improving recycling rates and reducing landfill waste", "Effective waste segregation helps to minimize contamination in recycling streams, making recycling processes more efficient" and so on. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.845$).

Recycling programs factor was measure using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Recycling programs are designed to divert waste from landfills and recover valuable materials", "The success of recycling programs often depends on public participation and community engagement" and so on. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.841$).

Household participation were measure using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Household participation is key to the

success of waste management and recycling initiatives", "Many households face barriers to participation, including lack of space for recycling bins and limited information" and so on. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.890$).

Environmental challenges was measure using a 5-point Likert scale where the respondents were asked to indicate the responses using 5 for strongly agree and 1 for strongly disagree. There are 5 items and sample items include "Improper waste management contributes to serious environmental challenges, including pollution and climate change", "Urban areas often face unique challenges in managing solid waste due to high population density and limited space" and so on. The following section describes the independent variables used in this study along with the hypothesis formulation. The reliability of the feature was measured by computing the Cronbach's alpha ($\alpha = 0.900$).

The following section describes the independent variables used in this study along with the hypothesis formulation.

Recycling Programs

Recycling programs are organized systems designed to collect, process, and reuse materials from waste that would otherwise be discarded. Wilson *et al.* (2012) found that effective recycling programs require comprehensive planning and the integration of technological solutions to ensure efficient sorting and processing of recyclable materials. Similarly, Metin *et al.* (2003) stated that there is a significant and positive relationship exist between recycling programs and waste management in Turkey. Strengthening regulations, investing in advanced recycling technologies, and fostering partnerships between public and private sectors are critical for enhancing the effectiveness and sustainability of recycling programs (Ellen MacArthur ., 2017). Based on it, this study develops the following hypothesis:

$H_{1:}$ There is a positive relationship between recycling programs and solid waste management.

Household Participation

Household participation refers to the active involvement of individuals or families in activities or initiatives aimed at achieving a common goal, often within the context of community development, environmental sustainability, or public policy. According to Stern (2000), participation by households is influenced by a combination of internal factors, such as environmental attitudes, and external factors, such as social norms and incentives. The participation of households is essential in areas such as municipal solid waste management. Household waste segregation at the source significantly improves recycling rates and reduces the environmental impact of improper waste disposal (Guerrero *et al.,* 2013). However, Thomas and Sharp (2013) highlighted that well-designed awareness campaigns and incentive programs can significantly enhance household participation in waste segregation and recycling initiatives. Likewise, Abrahamse *et al.* (2005) found that the importance of tailored interventions, including feedback and incentives, to encourage sustainable energy behaviors among households. Based on it, this study develops the following hypothesis:

H_2: There is a positive relationship between household participation and solid waste management.

Municipal Solid Waste Management

Municipal solid waste management (MSWM) refers to the comprehensive system that encompasses the collection, transportation, treatment, recycling, and disposal of waste

generated by households, commercial establishments, institutions, and industries within a municipality. This process is critical for maintaining public health, safeguarding the environment, and promoting sustainable development (Guerrero *et al.,* 2013). Similarly, Turan, *et al.* (2009) found that municipal solid waste management has a direct and positive impact on the solid waste management. The study highlighted that the importance of community awareness and behavior in achieving effective waste management (Wilson *et al.,* 2006). Based on it, this study develops the following hypothesis:

H_3: There is a positive relationship between municipal solid waste management and solid waste management.

Waste Segregation

Waste segregation is the systematic process of separating waste materials into different categories based on their characteristics, such as recyclability, biodegradability, and hazard level. Zurbrugg *et al.* (2012) found that the source separation is most successful when individuals and communities are educated about the importance of waste segregation and provided with appropriate facilities such as separate bins and collection services. Similarly, Siegrist (1977) sated that waste segregation as a means of enhancing onsite wastewater management. According to Guerrero *et al.* (2013), waste segregation involved the classification of waste at the source into various streams such as organic, recyclable, and non-recyclable waste, which facilitates proper disposal, recycling, and resource recovery. The study ensures that recyclable materials are diverted from landfills and reused, thereby conserving natural resources and reducing greenhouse gas emissions (Wilson *et al.,* 2006). Based on it, this study develops the following hypothesis:

$H_{4:}$ There is a positive relationship between waste segregation and solid waste management.

Environmental Challenge

Environmental challenges refer to the significant issues that threaten the health of the planet and its ecosystems, often caused by human activities. These challenges can affect climate, biodiversity, air, water, and soil quality, as well as human health and well-being. Rockstrom *et al.* (2009) found that environmental challenges often occur when human activities exceed the planet's ecological boundaries, thereby threatening the Earth's capacity to support life and maintain ecological balance. Similarly, Landrigan *et al.* (2018) explored pollution is the leading environmental cause of disease and premature death globally, responsible for approximately 9 million deaths annually. Likewise, Elsaid and Aghezzaf (2015) stated that environmental challenges directly impact on the waste management. Based on it, this study develops the following hypothesis:

H_5: There is a positive relationship between environmental challenges and solid waste management.

3. Results and discussion

Correlation analysis

On analysis of data, correlation analysis has been undertaken first and for this purpose, Kendall's Tau correlation coefficients along with means and standard deviations have been computed, and the results are presented in Table 1.

Table 1

Kendall's Tau correlation coefficient matrix

This table presents Kendall's Tau coefficients between dependent variable and independent variables. The correlation coefficients are based on 125 observations. The dependent variable is SWM (Solid waste management).The independent variables are MSWM (Municipal solid waste management), WS (Waste segregation), ES (Recycling programs), HP (Household participation) and EC (Environmental challenges).

Variable	Mean	SD	SWM	MSWM	WS	RP	HP	EC
SWM	3.763	1.025	1					
MSWM	3.699	1.011	0.655	1				
WS	3.616	0.926	0.556	0.619	1			
RP	3.554	0.914	0.495	0.514	0.596	1		
HP	3.627	0.968	0.608	0.640	0.606	0.603	1	
EC	3.750	0.991	0.683	0.635	0.568	0.522	0.667	1

Notes: The asterisk signs (**) and (*) indicate that the result are significant at one percent and five percent levels respectively.

Table 1 shows the Kendall's Tau correlation coefficients of dependent and independent variables. The study shows that municipal solid waste management is positively correlated to solid waste management. It means that increase in municipal solid waste management practices leads to increase in solid waste management. Similarly, there is a positive relationship between waste segregation and solid waste management. It means that effective waste segregation leads to increase in solid waste management. Likewise, recycling programs has a positive relationship with solid waste management. It shows that efficient management of recycling programs leads to increase in solid waste management. Furthermore, there is a positive relationship between household participation practices and solid waste management. It indicates that increase in household participation practices leads to increase in solid waste management. Moreover, environmental challenges has a positive relationship with solid waste management. It indicates that increase in environmental challenges practices leads to increase in solid waste management.

Regression analysis

Having indicated Kendall's Tau correlation coefficients, the regression analysis has been carried out and the results are presented in Table 2. More specifically, it presents the regression results of municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges on solid waste management in Kathmandu, Nepal.

Table 2

Estimated regression result of municipal solid waste management, waste segregation, recycling programs, household participation, and environmental challenges and solid waste management of solid waste collection and segregation in Kathmandu

The results are based on 125 observations using linear regression model. The model is $SWM = \beta_0 + \beta_1 MSWM + \beta_2 WS + \beta_3 RP + \beta_4 HP + \beta_{5E} C + e$ where the dependent variable is SWM (Solid waste management). The independent variables are MSWM (Municipal solid waste management), WS (Waste segregation), ES (Recycling programs), HP (Household participation) and EC (Environmental challenges).

Models	Intercepts	Regression coefficients of					Adj. $R\ bar^2$	SEE	F- Value
		MSWM	WS	RP	HP	EC			
1	0.600 (3.183)**	0.855 (17.409)*					0.709	0.553	303.064
2	0.767 (3.101)**		0.829 (12.494)				0.556	0.683	156.091
3	0.849 (3.351)**			0.820 (11.877)			0.530	0.703	141.059
4	0.664 (3.134)**				0.855 (15.143)		0.648	0.608	229.306
5	0.498 (2.548)**					0.871 (17.258)*	0.705	0.557	297.828
6	0.414 (2.060)**	0.699 (8.529)	0.211 (2.359)				0.719	0.543	159.938
7	0.284 (1.408)**	0.665 (8.227)	0.019 (0.172)	0.268 (2.753)**			0.734	0.529	114.902
8	0.225 (5.451)**	0.527 (0.955)	-0.018 (1.661)	0.198 (5.802)**	0.262 (0.295)		0.747	0.516	92.333
9	0.146 (0.773)**	0.409 (4.316)	-0.081 (-0.772)	0.184 (1.967)**	0.094 (0.916)	0.375 (3.775)**	0.772	0.489	84.872

Notes:

i. Figures in parenthesis are t-values
ii. The asterisk signs (**) and (*) indicate that the results are significant at one percent and five percent level respectively.
iii. Solid waste management is the dependent variable.

Table 2 shows that the beta coefficients for municipal solid waste management are positive with the solid waste management in Kathmandu. It implies that municipal solid waste management has a positive impact on solid waste management. This finding is consistent with the findings Wilson *et al.* (2006). Likewise, the beta coefficients for waste segregation are positive with the solid waste management. It indicates that waste segregation has a positive impact on solid waste management. This finding is consistent with the findings of Guerrero *et al.* (2013). Further, the beta coefficients for recycling programs are positive with the solid waste management. It indicates that recycling programs have positive impact on solid waste management. This result is consistent with the findings of Metin *et al.* (2003). In addition, the beta coefficients for household participation are positive with the solid waste management. It indicates that household participation has a positive impact on the solid waste management. This finding is similar to the findings of Thomas and Sharp (2013). Further, the beta coefficients for environmental challenges are positive with the solid waste management. It indicates that environmental challenges have positive impact on solid waste management. This finding is consistent with the findings of Landrigan *et al.* (2018).

4. Summary and conclusion

Solid waste collection and segregation are key components of an effective waste management system. Proper collection and segregation reduce the amount of waste sent to landfills, enhance recycling efforts, and protect the environment by reducing pollution and conserving resources. Solid waste management, including collection and segregation, in Kathmandu, the capital city of Nepal, faces significant challenges due to rapid urbanization, population growth, and limited infrastructure. However, the city has been making efforts to improve its waste management system, with some successes and areas for improvement. Solid waste collection and segregation are essential for reducing waste, conserving resources, and protecting the environment. By implementing effective segregation systems and educating the public, we can improve recycling rates, reduce landfill use, and foster a cleaner and more

sustainable world. The key is making sure the right materials are properly separated at the source, ensuring that waste management systems are more efficient, cost-effective, and eco-friendly.

This study provides insightful information regarding the solid waste collection and segregation in Kathmandu. The study analyzes various significant variables that could impact solid waste management in Kathmandu, Nepal. These variables include how municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges influence solid waste management in Kathmandu,

This study attempts to examine the impact of solid waste collection and segregation in Kathmandu. The study is based on primary data with 125 observations.

The major conclusion of the study is that municipal solid waste management, waste segregation, recycling programs, household participation and environmental challenges have positive impact on solid waste management. The study also concluded that municipal solid waste management is the most significant factor followed by environmental challenges, household participation, waste segregation and recycling programs that influences the factors affecting solid waste management in Kathmandu, Nepal.

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