



## Strategic Advancements in Rural Waste Management: Insights and Innovations for Sustainable Practices

*Masoumeh Pasavideh*<sup>1</sup>

<sup>1</sup>Department of Geography, Faculty of Social Sciences, Payame Noor University, Gilan, Iran, ORCID: 0009-0001-1189-4076

ORCID: 0000-0002-7763-9780, Email: [rahavarde.91@gmail.com](mailto:rahavarde.91@gmail.com)

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### ABSTRACT

**Background:** Rural waste management is a pivotal aspect of environmental sustainability, public health, and community welfare. This review delves into the multifaceted challenges and solutions pertinent to waste management in rural settings, providing a fresh perspective on the integration of advanced and sustainable practices.

**Objective:** The purpose of this article is to amalgamate insights from various studies to furnish policymakers, waste management professionals, and researchers with innovative strategies and actionable recommendations tailored to the rural context.

**Methods:** A comprehensive literature review was undertaken, drawing from an array of sources such as Web of Science, Scopus, and Google Scholar. The focus was to collate and synthesize studies that addressed the unique facets of rural waste management, highlighting both traditional practices and technological innovations.

**Results:** The research underscored the critical role of source separation in enhancing waste management efficiency. It revealed the necessity of considering socio-economic, climatic, geographic, cultural, and demographic factors in crafting effective waste management frameworks. Innovative practices such as home composting and the use of digital coupon systems emerged as potent tools in managing agricultural waste and curtailing greenhouse emissions. Moreover, structural factors crucial to optimizing rural waste management strategies were identified and discussed.

**Conclusion:** This review emphasizes the need for mandatory source separation and bespoke waste management strategies sensitive to rural dynamics. It advocates for the widespread adoption of home composting and digital solutions to manage waste and mitigate environmental impact. Enhancing public engagement through educational initiatives and community-driven programs is also crucial. Further research should aim at refining and adapting these strategies to meet the specific demands and characteristics of rural areas.

**Keywords:** rural waste management, sustainable strategies, waste separation, technological innovations, agricultural waste management, environmental impact.

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### Introduction

The rapid growth of population in both urban and rural areas has led to a significant increase in waste and garbage, which is often transferred from urban centers to rural areas. Changes in household lifestyles, increased consumerism, and improved living standards have also contributed to the production of more waste in both urban and rural communities (Bashir et al., 2021; Oyedele et al., 2021). In underdeveloped and rural communities, where living standards are often very low, comprehensive waste management is required to improve the situation and bring these communities up to a desirable level (Sarkodie & Owusu, 2021; Zhu et al., 2021). However, waste management is one of the most significant challenges currently facing the world (Rocheng & Badloo, 2020), and inadequate waste management in many developing countries leads to environmental pollution, global warming, and health impacts (Negin et al., 2020).

The management of waste in both urban and rural areas has become a crucial necessity in developing countries, where population growth is occurring at a faster rate than in developed countries, leading to increased consumption and waste generation (Kabir & Khan, 2020). Solid waste has emerged as a major environmental concern, and new waste management plans are necessary to address the increase in waste and its known impacts on nature and humans (Edjou et al., 2020).

Economic and cultural factors, urban structure, land use, population density, seasons, and social indicators affect the quality and volume of waste production (Mahmoud Bahramkhah et al., 2021). Proper waste management is crucial for rural settlements, as waste pollutants can spread to agricultural lands and pose a risk to public health (Singh & Kumar, 2021; Kaur & Kumar, 2020). In developing countries, where waste management infrastructure is often inadequate, rural areas are particularly vulnerable to the negative impacts of waste pollution (Fagbohun & Adekunle, 2020). Therefore, prioritizing sustainable waste management practices in rural areas is essential to prevent the spread of waste pollutants and protect public health (Awasthi et al., 2017). The objective of this review is to assess the current state of waste management practices in rural settlements, evaluate the effectiveness of existing waste management strategies in preventing the spread of waste pollutants to agricultural lands, and identify key challenges and opportunities for sustainable waste management in rural areas. The review aims to recommend strategies for improving waste management practices in these communities and contribute to the development of sustainable waste management policies and practices.

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## Current state of waste management in rural settlements

### *Waste definition*

Solid waste is defined as useless and often hazardous materials that contain moisture (Perera & Fernando, 2019), including municipal waste, industrial and commercial waste, sewage sludge, and waste from agricultural and livestock activities. Numerous sources in urban areas contribute to solid waste production, including residents, commercial activities, and private and public institutions (Shokouhi, 2009). The size and structure of the waste produced depend on various economic, social, cultural, and geographical conditions. According to a World Bank report in 2016, the amount of waste produced globally was 2.01 billion tons, of which 33% was never managed environmentally and was instead littered or burned. Furthermore, it is predicted that by 2050, the amount of solid waste produced annually will reach 3.40 billion tons (Kaza et al., 2018). "Waste" is a highly subjective concept. What one person considers waste may be a resource for another (Amasuomo & Baird, 2016). According to the Organisation for Economic Co-operation and Development, "waste" refers to "materials that are not currently needed and are the unavoidable result of human activity, and for which processing or disposal is necessary" (OECD, n.d.). The United Nations Environment Programme's environmental program also defines waste as "objects that their owners do not want, do not need, or do not use, and that must be processed or disposed of" (UNEP, n.d.). Therefore, physically, waste consists of the same materials as useful products, and the only difference is their worthlessness. In many cases, this worthlessness is due to the mixing and unknown nature of the materials in the waste (Nourpour et al., 2013). Therefore, waste can be described as items that have no use for individuals or companies and are intended to be discarded or have already been discarded (Ngoc & Schnitzer, 2009) and come in various forms.

### *Waste classification*

The classification of different types of waste will vary based on their various properties such as physical characteristics, reusability, biodegradability, source of production, and the extent of environmental impact (Amasuomo & Baird, 2016). The most common classifications include physical state (solid, liquid, gas), source (household, industrial, agricultural, commercial, demolition and construction, mining), and environmental impact (hazardous and non-hazardous).

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## According to the Waste Management Act, waste is divided into five groups:

1. **Normal waste** (resulting from daily activities in urban and rural areas such as household waste and construction debris),
2. **Medical or hospital waste** (including infectious and harmful waste produced by hospitals, health centers, clinics, and laboratories),
3. **Hazardous waste** (possessing at least one hazardous property such as toxicity, infectivity, explosiveness, flammability, and corrosiveness),
4. **Agricultural waste** (such as animal waste, animal carcasses, and spoiled or unusable agricultural products),
5. **Industrial waste** (resulting from industrial and mining activities, refineries, gas, oil and petrochemical industries, and power plants such as industrial waste, spills, and sludge) (Islamic Consultative Assembly, 2004).

### *Waste management in rural areas*

The rural area is a unique social unit that has a two-way relationship with its environment, and this space plays an essential role as a necessary principle in the rural social system. Therefore, the village has a social aspect that can be considered one of its fundamental reasons for formation (Plasiderambod, 1976). Solid waste management refers to all stages related to the collection of waste produced in urban areas and its transfer to remote areas around the city for processing and finally burial according to health laws (Shokder, 2009). With the increase in population and the transformation of people's lifestyles, simple solutions for solving the problems related to waste disposal management are not enough. This is while there are no independent organizations for managing all stages of urban solid waste (Manikpura et al., 2013; Liam Sanggan & Qiouala, 2008). Integrated solid waste management refers to a strategic approach to sustainable solid waste management by comparing all resources and aspects and covering all stages of production, separation, transportation, classification, purification, recycling, and disposal in an integrated manner and emphasizing maximum resource utilization (Liam Sanggan et al., 2008). The implementation of an integrated urban waste management system faces many difficulties and obstacles, especially in developing countries due to rapid urbanization and consumerism. Only developed countries with adequate technical, social, economic, and environmental goals have successfully implemented such systems. Among the challenges of implementing integrated urban waste management in developing countries are the following:

- (1) The rapid population growth in developing countries creates a greater capacity issue in waste management;
- (2) Public health, the environment, and waste management are interconnected, and improper waste management can affect both public health and the environment, leading to numerous problems in waste management systems;
- (3) Waste management classification is one of the most complex challenges and requires a wide range of options, including purification, composting, and recycling; and
- (4) Limited knowledge about waste segregation at the source plays a crucial role in calculating the amount of waste that can be recycled. The amount of waste that can be segregated depends on factors such as the collection system, the quality of waste segregation, and the level of citizen participation (Kumar, 2018).

Regardless of the type of waste, its producer or place of production, measures must be taken to minimize its production, emission, and recovery (Rayner et al., 2011), which highlights the importance of waste management.

Waste management is the process of controlling the production, storage, collection, transportation, conversion or recycling, and disposal of waste, using the most optimal principles and practices to ensure compliance with health, economic, social, engineering, aesthetic, administrative, financial, legal, and planning considerations (Manouri, 2002). According to another definition, waste management is a set of engineering and health practices aimed at organizing community waste (Veigel, 2009). In this regard, the "rural waste management system" consists of various components referred to as "mandatory elements and support functions." Therefore, rural waste management is a continuous set of components created to address waste management problems in rural areas. Rural waste management has six mandatory elements, including production, on-site storage, collection, transportation, recovery, and disposal. Support functions include financial, equipment, staff, public relations, contracts, and so on (Darban Astaneh et al., 2017).

Studies show that waste management and planning in developing countries have a long history, and these countries view waste not as a threat, but as an opportunity to produce goods and energy. In Iran, appropriate laws and regulations in the field of waste management did not exist until recently, and the approval of the Comprehensive Waste Management Law by the Islamic Consultative Assembly in 2004 was the first step in this regard. According to Article 10 of this law, the Ministry of Interior is responsible for managing solid urban and rural waste. The responsibility for collecting and disposing of solid waste in rural areas lies with the village councils (Abduli et al., 2008).

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### **Unsuccessful waste management practices in rural areas: A case study of Langarud County and Khamiran village in Bandar Anzali County**

Currently, rural areas lack a unified and cohesive waste management system, such as a municipality responsible for waste management, or such systems are not yet fully developed. Rural areas also have low public income, and waste management requires greater support. Pollution caused by the waste produced directly and indirectly affects river water and agricultural land (Ali Akbar Anabestani, 2016). Unfortunately, rural residents often lack sufficient knowledge and appropriate tools for timely management of solid waste and resort to hazardous methods such as burning or leaving waste behind (Cooke, E., See, L., Woolliams, S., 2020). With the increase in the production of plastic materials in factories and the entry of these materials into the environment, today's humans are facing a not-so-strange crisis that necessitates preserving the human habitat by improving living conditions in rural areas through proper waste management. The importance of waste management in cities and villages near wetlands, which are home to many animals and plants, is an essential and undeniable issue. Inadequate waste management and planning in Bandar Anzali County, especially in Khamiran village, where urban and rural waste has accumulated, endangers the region's ecosystem due to its proximity to the wetlands, rain, and subsequent contamination of soil and groundwater, unpleasant odor, and the risk of insect infestation, especially during warm seasons, which leads to the emergence of various diseases common to humans and animals (Mojtaba Piray, 2017). The importance and urgency of this research have doubled. The importance and necessity of sanitary waste disposal in rural areas will only become clear when the risks associated with it are well understood (Mahmoud Bahrahaw and colleagues, 2021). Improper waste disposal has been the first and simplest solution for humans for many years, and the problems of waste disposal have always been a challenge for researchers to find a solution. Today, waste management is one of the main pillars of sustainable development, and in other words, the primary skill of solid waste management is limiting the environmental impacts of waste on the environment, and it is expected that these impacts will be reduced to a minimum through reducing waste production, reuse of waste, and recycling (Mahmoud Bahrahaw and colleagues, 2021). The first step in planning a waste management system is identifying the production and characteristics of waste (Siafrodin and colleagues, 2022). Langarud County in Iran is an example of unsuccessful waste management practices in rural areas. The county has a high amount of rural waste without successful management, which harms the environment and agriculture. The residents of Langarud County dispose of their waste in open areas or burn it, leading to air pollution and soil contamination. The uncontrolled dumping of waste also threatens the health of the residents and causes problems for the local wildlife. The lack of proper waste management infrastructure in Langarud County is a major contributing factor to the problem. There are no waste collection systems or recycling facilities in the area, and the local authorities have not implemented any waste management programs. The residents are also not educated on proper waste disposal practices, and there is a lack of awareness about the negative impact of improper waste management on the environment and health. The consequences of poor waste management in Langarud County are severe. The contamination of soil and water resources harms both agricultural production and local wildlife. The lack of proper waste disposal facilities also leads to the spread of diseases and poses a risk to public health.

To address the issue, the local authorities in Langarud County need to implement a comprehensive waste management program that includes waste collection, segregation, and disposal. The program should also focus on educating the residents on proper waste disposal practices and the negative impact

of improper waste management on the environment and health. The development of recycling facilities could also help to reduce the amount of waste generated in the area and promote a more sustainable approach to waste management.

Indeed, Langarud County is an example of the negative consequences of poor waste management practices in rural areas. The lack of proper infrastructure, education, and awareness on the issue has led to severe environmental and health problems. It is essential to implement comprehensive waste management programs in rural areas to ensure the sustainable management of waste and protect the environment and public health.

#### ***Strategies for sustainable waste management in rural areas***

Karim Amara (2023) investigated the waste management system in rural areas of Faiyum province, Egypt, and selected three villages as study areas due to the weakness of the waste management system. The study aimed to evaluate the waste management system and select a suitable treatment center for improving the waste management system. The study found that the organic percentage in these three villages was high, ranging from 67% to 80%, indicating that composting and anaerobic digestion scenarios are potential options for sustainable waste management. The composting scenario was found to be the best solution for the current situation of solid urban waste, saving EGP 1,365,043 annually during the project period (Amara, 2023). This solution is also useful due to the availability of areas in the Faiyum province, and it can be used to revive the land because the Egyptian government has started to revive a large desert area near these villages.

Siafrodin and colleagues (2023) conducted a study in the southern region of Gunungkidul with the aim of measuring and analyzing the waste characteristics in 16 randomly selected villages using the Indonesian National Standard method. The study found that the average waste production was 0.29 kilograms per person per day, indicating that waste production in the study area is classified as small towns. 75% of the solid waste generated is food waste and leaves. This study suggests that source reduction and waste minimization practices can be implemented in this area to reduce the amount of waste generated (Siafrodin et al., 2023).

These studies highlight the importance of sustainable waste management practices in rural areas. Strategies such as composting, anaerobic digestion, source reduction, and waste minimization can be effective in promoting sustainable waste management practices in rural areas. However, financial and institutional support, innovations, and technology adoption, as well as policy and regulatory frameworks, are necessary to ensure the successful implementation of these strategies. Policymakers, practitioners, and researchers should work together to identify and implement effective waste management strategies in rural areas.

According to the study by Siafrodin and colleagues (2023), the waste composition in the southern region of Gunungkidul, Indonesia, showed that paper, plastic, glass, wood, other materials, and fabric accounted for 11.8%, 10.1%, 1.7%, 0.5%, 0.5%, and 0.4%, respectively. The study also found that the waste density in this region was high at 110.6 kg/m<sup>3</sup>, indicating that less recyclable waste was produced in the area. Factors such as economic activity, lifestyle, geographical conditions, and urban center attractiveness influence waste production and composition in rural areas. However, the characteristics of waste generated in this region do not differ significantly from those in most rural areas of developing countries. The management of rural waste should prioritize organic waste as the main material for management. Processing organic waste through composting could be a future solution, but the active role of residents is crucial for its success. Additionally, this method can help increase the lifespan of landfill capacity, as the volume of organic waste is reduced by half.

The study by Marti et al. (2020) on food waste composting policies and their consequences for rural areas is also relevant to this section. The study surveyed the understanding of food waste and current and future food waste management behaviors of residents in Vermont, one of the rural states in the United States, through a telephone survey of representative residents (n = 583) in 2018. The findings showed that 55% of residents supported the ban on food waste in landfills. Moreover, 72% of the residents currently composted at least part of their food waste, and over 75% predicted they would do so in the future. In contrast, 34% of residents predicted that they would use waste or sideline composting programs in the future. Most respondents were not willing to pay anything extra for sideline composting programs. These results suggest that waste management strategies in rural areas may differ from those in densely populated areas, especially for programs that may require significant investment and given the popularity of home composting. Therefore, increased investment in education and infrastructure for backyard composting may be an important part of rural food waste management.

The study by Zeng and colleagues (2016) on public perception and economic values of solid waste collection in rural China suggests that source separation is the main component of an integrated waste management system.

#### ***Various studies and research conducted on rural waste management***

In their 2017 study on solid waste management, Mo and Abdul Manaf identify source separation and recycling as the most realistic solution for the future challenges of waste management and recycling in Malaysia, which has been successful through its mandatory and legal enforcement.

Mehi and Inggraw (2018) introduce home composting as a sustainable method for reducing waste and greenhouse gas emissions compared to the disposal of organic waste in open areas or landfill sites, in their research titled "Assessing the Environmental Damage of Waste Management Methods in Rural Areas".

Han and colleagues (2018) examine the factors affecting the characteristics of household waste in rural areas of developing countries and emphasize the importance of various socio-economic, climatic, geographical, cultural, population density, and other variables for rural solid waste management.

In their 2019 research titled "Win-Win Results in Waste Separation Behavior in Rural Areas of Vietnam," Nguen and Vatanab consider waste separation at the source as a necessity, taking into account the difference in rural lifestyle compared to other areas.

Zhang (2019) examines the impact of promoting digital coupon technology on encouraging rural solid waste management, indicating that this method is effective in managing agricultural waste and converting it into fertilizer and animal feed, leading to improved environmental quality.

Manijeh Ahmadi and Mahri Jahansouz (2021) conducted a descriptive-analytical study titled "Analysis of Effective Factors in Rural Waste Management in Shirin Darreh Village, Quchan County," and used a combination of document survey and data collection methods such as observation, interview, and questionnaire to collect data from 347 rural household heads in Shirin Darreh Village. The collected data was analyzed using SPSS and LISREL software, and exploratory factor analysis was used to identify the factors related to the structure of "Effective Factors in Rural Waste Management in Shirin Darreh Village." The results showed that ten factors, including final disposal management, education and awareness, cultural, health, knowledge and awareness, inter-sectoral, financial, organizational, planned programs, and social factors, explain almost 67.51% of the total variance. Confirmatory factor analysis also showed that these ten factors largely measure the independent and discrete dimensions of "Effective Waste Management Factors" in the study area.

Mohammad Akbarpour and colleagues (2021) conducted a study entitled "Analysis of Rural Waste Management using PLS Structural Model Analysis (Case Study: Mahidashat District, Kermanshah City)". The research is both descriptive and analytical in terms of its objective and methodology. The research variables are categorized into three social-cultural dimensions, which include indicators such as waste separation, local community participation, and attention and awareness of local managers. The economic dimension includes indicators such as public costs and the importance of recycling, while the institutional-environmental dimension includes indicators such as traditional and unhygienic burial, lack of facilities and establishments, creating space for waste recycling away from the village, and animal waste. The PLS structural model was used to measure the relationship between research variables and waste burial methods. The results indicate that waste management in the studied rural areas is not in a suitable condition. Based on the research findings and the estimated structural equation model of PLS, the results show a correlation between the attention and awareness of officials and local managers and the direct effect of the existence or absence of necessary facilities and establishments in the region for collecting and disposing of waste. These issues have directly and indirectly led to a lack of local community participation, and ultimately, rural waste is buried unhygienically or stored in a corner of the village.

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## **Conclusion and Recommendations**

### ***Summary of Key Findings and Contributions***

This review article aimed to explore various studies and research conducted on rural waste management. The studies reviewed highlighted the importance of waste separation at the source as a necessity and emphasized the need for socio-economic, climatic, geographical, cultural, population density, and other variables for rural solid waste management. The reviewed studies showed that home composting can be a sustainable method for reducing waste and greenhouse gas emissions. Digital coupon technology was found to be effective in managing agricultural waste and converting it into fertilizer and animal feed, leading to improved environmental quality. The studies also identified factors related to the structure of "Effective Factors in Rural Waste Management." These factors included final disposal management, education and awareness, cultural, health, knowledge and awareness, inter-sectoral, financial, organizational, planned programs, and social factors.

### ***Implications and Future Directions for Sustainable Waste Management***

The studies reviewed in this article have several implications for sustainable waste management in rural areas. Waste separation at the source should be mandatory and legally enforced. Policymakers and waste management practitioners should consider socio-economic, climatic, geographical, cultural, population density, and other variables for rural solid waste management. Home composting should be encouraged as a sustainable method for reducing waste and greenhouse gas emissions. Digital coupon technology should be promoted to manage agricultural waste and convert it into fertilizer and animal feed, leading to improved environmental quality. The factors related to the structure of "Effective Factors in Rural Waste Management" should be considered when designing waste management policies and practices in rural areas.

Additionally, the studies reviewed in this article highlighted the importance of public awareness and participation in rural waste management. Education and awareness campaigns should be launched to educate rural communities on the importance of waste management and the benefits of sustainable practices. The campaigns should aim to raise public awareness of the environmental, social, and economic impacts of poor waste management practices. Additionally, community participation should be encouraged through the creation of local waste management committees, public consultations, and community-based waste management programs. The involvement of local communities in waste management programs can increase their sense of ownership and responsibility and lead to improved waste management practices.

Future research directions should focus on identifying other effective waste management practices and policies that are suitable for rural areas. The studies reviewed in this article highlight the need for a multidisciplinary approach to rural waste management, taking into account socio-economic, climatic, geographical, cultural, population density, and other variables. Further research can help policymakers and waste management practitioners to design effective waste management policies and practices that are tailored to the specific needs and characteristics of rural areas.

### ***Recommendations for Policymakers, Practitioners, and Researchers***


Based on the findings of the reviewed studies, policymakers, practitioners, and researchers can take the following recommendations to improve waste management practices and policies in rural areas:

1. Enforce mandatory and legal waste separation at the source.

2. Consider socio-economic, climatic, geographical, cultural, population density, and other variables for rural solid waste management.
3. Encourage home composting as a sustainable method for reducing waste and greenhouse gas emissions.
4. Promote digital coupon technology to manage agricultural waste and convert it into fertilizer and animal feed, leading to improved environmental quality.
5. Consider the factors related to the structure of "Effective Factors in Rural Waste Management" when designing waste management policies and practices in rural areas.
6. Launch education and awareness campaigns to educate rural communities on the importance of waste management and the benefits of sustainable practices.
7. Encourage community participation through the creation of local waste management committees, public consultations, and community-based waste management programs.
8. Conduct further research to identify other effective waste management practices and policies that are suitable for rural areas and take into account the specific needs and characteristics of rural communities.

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