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Proposal for the Largest Waste Management in Landfills in Indonesia for Environmental Sustainability and Public Health

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ABSTRACT

This study examines the impact of waste management policies on public health in Bantar Gebang landfill which faces challenges such as inadequate infrastructure, low community participation, and ineffective policy implementation. More than half of the waste generated is not transported to landfills, resulting in significant health and environmental risks, including respiratory infections, waterborne diseases, and vector-borne illnesses. The research adopts a qualitative phenomenological approach to understand the experiences of stakeholders, waste managers, and local communities. It also integrates the Waste Management Hierarchy, Community Participation Theory, and Policy Implementation Model to identify key gaps and propose potential solutions. The study reviews legal frameworks, including Indonesia's Presidential Regulation No. 97 of 2017, and specific regulations relevant to the site, evaluating their effectiveness in addressing waste and health issues. The findings highlight the need for stronger public education campaigns, increased investment in infrastructure, and the implementation of advanced technologies such as Waste-to-Energy plants. The study stresses that comprehensive policies on waste reduction, improved segregation, and better recycling practices are critical for achieving sustainable waste management. Additionally, greater inter-agency collaboration and active community engagement are essential for ensuring successful implementation. Drawing on experiences from Tokyo, Stockholm, and Berlin, the study suggests strategies to reduce landfill dependence and improve public health.

Keywords: Waste Management; Environmental Health; Community Participation; Public Policy Implementation; Sustainable Urban Planning

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1. Introduction

Urban planning generally includes arrangements to control air pollution and disease prevention, focusing on drainage system management^[1]. It is argued that these regulations should also encompass the management of organic and inorganic waste, particularly waste management systems that do not pollute the environment. This is due to the increasing complexity of waste management problems triggered by low public awareness, limited technical knowledge, and inadequate regulations^[2].

Urban planning and waste management in Tokyo, Paris, and New York City illustrate how well-designed urban planning can support effective waste management. Although each city faces different challenges and implements unique solutions, the basic principle of integrating urban planning and waste management is applied consistently. Effective waste management relies on advanced processing systems and urban planning that support the necessary infrastructure and policies for sustainable waste management^[3].

Over the past two decades, waste management has become a priority in Indonesian provinces, cities, and regencies. Research by Widiyanto, Fathurakhman and Munadi^[4] identifies significant challenges in waste management, such as increasing waste production, urban mobility, and the complexity of urban functions. Research by Idilia, Ekayani and Nuva^[5] also reveals that, over the past five years, the volume of waste in major cities in Indonesia has increased significantly, along with the migration of people from rural areas to urban centers. This research highlights that weak communication, education, and information regarding the separation of wet and dry waste exacerbate the challenges in waste management. Furthermore, data from the Central Statistics Agency indicates that the rate of waste growth has increased by an average of 1.12% per year from 2020 to 2023. This increase in waste production is proportional to the rise in population from 2,126,451 to 2,543,676 people in 2023.

A survey conducted by the Environmental Agency of Bekasi City in 2023 showed that 75.22% of the waste transported to the Final Disposal Site in the area consisted of household waste, while the remaining 24.78% was inorganic waste. These findings highlight the importance of public awareness and collective action in managing household waste to reduce environmental impacts^[6].

The health impact of poor waste management in Bantar

Gebang is reflected in the data collected from nine community health centers. Among the population of 96,384 residents, a staggering 36,557 individuals (37.93%) have been affected by diseases associated with waste mismanagement. These diseases include respiratory illnesses, gastrointestinal infections, and skin conditions, primarily driven by prolonged exposure to pollutants from the landfill.

Respiratory issues, such as asthma and acute respiratory infections (ARI), are significantly prevalent due to continuous air pollution caused by illegal waste burning and methane emissions from decomposing organic matter^[7]. The high levels of methane (CH₄) and carbon dioxide (CO₂) not only threaten air quality but also exacerbate global warming. With its high greenhouse gas potential, methane amplifies the environmental and health risks, creating an unsafe living environment for the surrounding community^[8].

Waterborne diseases, including cholera and leptospirosis, are rampant due to groundwater contamination by landfill leachate^[9]. This leachate, rich in organic and chemical pollutants, infiltrates the soil and nearby water sources, making it unfit for consumption and daily use. Residents relying on wells for their water supply are particularly at risk, with children and the elderly being the most vulnerable groups. Diarrheal diseases, a direct consequence of water contamination, account for a significant proportion of the cases reported in the area.

Additionally, the presence of disease vectors, such as mosquitoes and rats, exacerbates the health challenges residents face. The spread of dengue fever and malaria has been closely linked to stagnant water in and around the landfill, which provides a breeding ground for these vectors. The inadequate waste disposal systems in residential areas have also contributed to the proliferation of flies, further spreading diseases and worsening living conditions.

Skin conditions such as hives and other dermatological issues have been reported frequently among residents, caused by direct contact with polluted water or air contaminated by harmful substances from the landfill. The unpleasant odors from decomposing waste, compounded by the emissions of harmful gases, further reduce the quality of life for the residents in this densely populated area.

Improper waste management practices in residential areas and waste processing sites cause an increase in these disease cases. The Bekasi City Environmental Agency re-

ported that in 2023, only around 55.3% of the total waste was successfully transported to the Sumur Batu landfill, leaving 44.7% uncollected and poorly managed by the government and the community. The low level of community participation in waste management is suspected to be a serious challenge for the government in maintaining environmental cleanliness. Factors believed to influence low community participation include low environmental awareness, lack of education, limited infrastructure, and minimal community involvement, which result in public dependency on the government for waste management. This issue must be addressed promptly in the future^[10]. Waste-to-Energy (WtE) transforms waste into usable energy through incineration, gasification, or anaerobic digestion, significantly reducing landfill volumes. Many developed countries integrate advanced emissions controls, strong regulations, and community engagement to ensure efficacy. Although costly, WtE complements recycling by processing non-recyclable residue, mitigating environmental impact, and contributing to sustainable energy production when implemented responsibly. Worldwide, it is pivotal to waste strategies.

This study aims to improve the effectiveness of government policies in managing household and inorganic waste and their impact on public health and the environment, such as the increased risk of disease transmission, allergies, dengue fever, and Acute Respiratory Infections (ARI) in Bekasi City. Community participation in waste management is also examined to understand the factors causing low public involvement. This research is expected to provide recommendations for future government policies and programs to increase public awareness and participation in maintaining a clean environment.

2. Materials and Methods

2.1. Study Locus

The study is conducted in Bantar Gebang, located on the border of Bekasi City and Jakarta, home to one of Indonesia's largest waste dumps. The landfill spans 113 hectares and receives waste from the Jakarta metropolitan area. On average, the landfill handles between 6,500 and 7,000 tons of waste daily, with rubbish piles reaching heights of 20 to 30 meters, primarily composed of food waste^[11]. Poor waste management in this area has led to significant declines in the

quality of settlements and population health. The mountains of waste in Bantar Gebang negatively impact the surrounding community, causing water and air pollution and various health problems^[12]. Air pollution, characterized by a foul odor, affects areas within a 15–20 km radius and intensifies during rainy weather, resulting in prolonged environmental pollution^[13].

2.2. Qualitative Method

This study employs a qualitative methodology with a phenomenological approach, which is particularly effective for exploring individuals' subjective experiences in the waste management system^[14]. The phenomenological approach is suitable because it enables researchers to investigate how individuals perceive and interpret waste management daily. By focusing on participants' lived experiences, this method uncovers insights often overlooked by other research methods^[15]. Stakeholders were chosen based on their direct or indirect roles in waste management, ensuring representation from various sectors, including local authorities, private waste operators, community leaders, and NGOs. This purposive sampling method ensures that diverse perspectives are included, covering policy, technical operations, and community-level experiences. Data saturation was reached when additional interviews no longer provided new insights or themes, indicating that the collected information was sufficiently comprehensive to address the research objectives.

Through this approach, the study aims to highlight community perspectives, providing valuable input for developing more effective waste management policies. It specifically examines how individuals assess existing waste management policies, their involvement in daily waste practices, and the health impacts of these practices on their lives^[16].

The study includes in-depth interviews with various stakeholders, such as city residents, waste experts, policy-makers, regional planning agency officials, and environmental agency staff, selected using purposive sampling^[17]. A semi-structured interview guide is prepared and tested on five residents to refine the questions. These interviews explore participants' experiences, challenges in waste management, perceptions of implemented policies, and the broader effects of waste mismanagement on public health. City residents' interviews are expected to reveal their firsthand experiences with poorly managed waste, such as health issues related to

environmental pollution and inadequate sanitation. In addition to interviews, direct field observations are conducted to better understand daily waste management practices. Observations provide context for the data collected through inter-

views, offering insights into the practical implementation of waste management policies and how they affect community health and environmental sustainability (Table 1).

Table 1. Informant.

No	Informant Name	Informants Number	Institution/Organization
1	Public Works and Housing	1	Ministry of Public Works and Housing
2	Head of Regional Planning Agency	1	Regional Planning Agency
3	Head of Environmental Agency	1	Environmental Agency
4	Waste Policy Expert	2	University
6	Waste Expert	2	University
7	The Staff of Environmental Agency and Landfill	8	Environmental Agency
8	Community Member	8	Residents

3. Results and Discussion

3.1. Health Impacts and Efforts to Improve Waste Management

The dire health statistics and environmental hazards underscore the urgent need for effective waste management strategies in Bantar Gebang. Without significant interventions to improve waste processing, reduce emissions, and mitigate groundwater contamination, the health and well-being of the local population will continue to deteriorate. Comprehensive policies and community engagement are critical to addressing these challenges and ensuring a sustainable future for the affected communities (Figure 1).

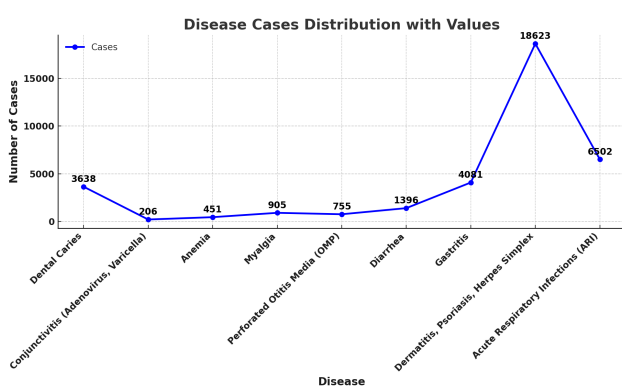


Figure 1. Number of disease cases caused by waste in community health centers.

Source: Public health centers in Bantar Gerbang area, 2024.

The analysis of disease case data reveals significant variability, with an average of 4,062 cases, but the distribution is highly uneven due to outliers such as Dermatitis,

Psoriasis, and Herpes Simplex, which account for 18,623 cases. The median of 1,396 better reflects the typical cases, indicating that most diseases have case numbers below the average. Cases range from 206 (Conjunctivitis) to 18,623, highlighting a significant disparity in disease prevalence. Common diseases such as Dental Caries, Acute Respiratory Infections (ARI), and Gastritis show moderate case numbers, while less-reported conditions such as Conjunctivitis may require more attention. This data underscores the need for targeted interventions for high-prevalence conditions while ensuring less common diseases are not neglected. It reflects the complexity of addressing diverse public health challenges effectively.

3.2. Waste Generation Conditions Data

The data on waste generation per district reflects the situation in Bekasi City, where approximately 46% of the total waste generated is collected and managed by the Bekasi City Environmental Agency. Conversely, about 52% of the waste remains uncollected, posing a significant issue for the local government as uncollected waste becomes a problem in the capital city. Table 2 provides data on waste generation per district in Bekasi City.

3.3. Waste Management Facilities

In Table 3, the number of medium-sized garbage trucks is currently 290 units, which can only transport 600–700 tons per day, and if calculated, the need for garbage trucks should be 877.

Table 2. Waste generation per ton in Bekasi City.

Year	Daily Waste Production (tons)	Annual Waste Production (tons)
2020	2,162.26	346,921.29
2021	2,258.86	400,340.05
2022	2,310.63	568,179.64
2023	2,375.99	577,236.75

Source: Bekasi City Environmental Agency, 2024.

Table 3. Number of garbage trucks and human resources.

Year	Number of Garbage Trucks	Number of Human Resources
2020	240	812
2021	254	898
2022	296	977
2023	336	993

Source: Bekasi City Environmental Agency, 2024.

- Calculating Future Needs

1. Determine the number of trucks needed.

Table 4 shows the number of trucks needed to transport 577,236.75 tons of waste per year, assuming the current number of trucks is 336 units capable of transporting between 600 and 700 tons per day.

To transport 577,236.75 tons of waste per year, assuming the daily carrying capacity per truck is about 1.93 tons, about 823 trucks are needed. Currently, there are 336 trucks, and additional trucks are needed to reach the required carrying capacity of 487 more trucks.

2. The need for future human resources

Table 5 illustrates the number of human resources required to operate 336 trucks in handling an annual waste production of 577,236.75 tons.

Around 12,275 human resources are needed to manage the annual waste production of 577,236.75 tons, with 336 trucks currently in existence. This number includes drivers, maintenance technicians, supervisors, administrative staff, and waste sorting and management employees. This estimate provides an overview of the workforce needs to support operational efficiency in waste management, although specific factors in the field may affect the final figure.

3.4. Analysis Resource Requirements

The increase in disease cases in areas like Bantar Gebang highlights the urgent need for effective waste management practices. This need becomes even more critical when examining waste generation and management in Bekasi

City. The Bekasi City Environmental Agency reported that only 46% of waste is collected and managed, leaving 52% uncollected. This uncollected waste contributes to health hazards and environmental pollution, as it often ends up in illegal dumpsites or is improperly disposed of in residential areas. The growing volume of waste, combined with insufficient collection and management facilities, underscores the significant challenges the local government faces.

Data on waste generation reveals a consistent increase in daily and annual waste production. From 2020 to 2023, annual waste production rose from 346,921.29 to 577,236.75 tons, while daily production increased from 2,162.26 to 2,375.99 tons. Despite this increase, the current waste management capacity remains inadequate. For instance, the number of medium-sized garbage trucks—290 units—is far below the required 877 trucks needed to handle the growing waste load. This shortfall translates into a need for an additional 487 trucks to meet waste transportation demands.

Similarly, the human resources required for effective waste management are significantly higher than current levels. With only 993 personnel in 2023, the estimated need is for 12,275 employees to handle the annual waste production of 577,236.75 tons. This workforce includes drivers, maintenance technicians, supervisors, administrative staff, and waste sorting and management employees. The discrepancy highlights a critical resource allocation gap, directly impacting waste collection and processing efficiency.

The connection between these challenges and health impacts is evident. Poor waste management leads to environ-

Table 4. Number of trucks needed in the future.

Step	Description	Account	Result
1. Determining the average daily carrying capacity	Total haul capacity per day with 336 trucks	600 tons + 700 tons/2	650 tons
2. Calculate the annual haul capacity of 336 trucks	No. of days in a year: 365 days	650 tons per day × 365 days	237,250 tons per year
3. Calculate the daily carrying capacity required	Annual waste production: 577,236.75 tons	577,236.75 tons/365 days	1,585.3 tons per day
4. Calculate the number of trucks required	Haul capacity per day per truck: 650 tons/336 trucks	1,585.3 tons per day/1.93 tons per truck	823 trucks

Table 5. The Amount of human resources needed in the future.

Step	Description	Account	Result
1. Carrying capacity per day of 336 trucks	Total haul capacity per day	650 tons	650 tons
2. Annual carrying capacity of 336 trucks	Calculate annual haul capacity	650 tons per day × 365 days	237,250 tons per year
3. Required daily carrying capacity	Calculate the daily haul capacity needed	577,236.75 tons/365 days	1,585.3 tons per day
No. of trucks required	Calculate the number of trucks needed	From 1,585.3 but green/from 1.93 per truck	823 trucks
5. No. of drivers	Drivers needed for 336 trucks (2 shifts/day)	336 × 2 trucks	672 drivers
6. No. of maintenance technicians	Technicians for every 10 trucks	336 trucks/10	34 technicians
7. No. of supervisors	Supervisor for every 20 trucks	336 trucks/20	17 supervisors
8. No. of administrative staff	Administrative staff for every 50 trucks	336 trucks/50	7 administrative staff
9. No. of waste sorting and management employees	Employees for every 50 tons of waste	577,236.75 tons/50 tons per employee	11,545 employees
Total no. of human resources needed			12,275

mental contamination, such as polluted groundwater and air, which fosters the spread of diseases like diarrhea, dermatitis, respiratory infections, and vector-borne illnesses. Proper waste collection and transportation systems, and adequate human resources, are essential to mitigate these risks.

Addressing these challenges requires a multi-faceted approach. Expanding the fleet of garbage trucks and recruiting additional personnel are immediate priorities to increase operational capacity. Furthermore, implementing community education programs to raise awareness about proper waste disposal and segregation is crucial to reducing the burden on waste management facilities. Integrating advanced technologies, such as automated sorting systems and AI-based waste tracking, can enhance efficiency and sustainability in waste handling.

The data from Bekasi City describes a direct link between inadequate waste management infrastructure and its broader implications on public health and environmental

quality. To resolve these issues, comprehensive planning, adequate resource investment, and robust policy enforcement are necessary to ensure sustainable waste management practices and improved living conditions for the affected communities.

3.5. Interview Results

The results of interviews with informants suggest that not all responses contribute equally to the core themes discussed. Therefore, we sort and present relevant information and discard responses that are less useful or excessive.

3.5.1. Waste Management Hierarchy Theory

Waste management in Bekasi City faces significant challenges that hinder the effectiveness of existing regulations and programs. Low public awareness is a major obstacle, leading to improper waste disposal. This increases health

risks from bacterial and viral infections and exacerbates environmental pollution. These challenges are further complicated by the limited infrastructure and human resources required to support an effective waste management system.

- **Truck Fleet Needs:** According to data, Bekasi City produces 577,236.75 tons of waste annually, requiring approximately 823 trucks for optimal transportation. Currently, only 336 trucks are available, leaving a shortfall of 487 trucks—this lack of capacity results in uncollected waste accumulating in illegal dump sites and residential areas.
- **Human Resource Needs:** At least 12,275 personnel are required to support waste management with a sufficient truck fleet. It includes 672 drivers, 34 maintenance technicians, 17 supervisors, 7 administrative staff, and more than 11,545 sorting and waste management workers. With only 993 workers currently employed, a significant increase in the workforce is needed to handle the growing volume of waste.

Staff (1) from the Environmental Agency:

“Our regulations are not optimally implemented due to low public awareness, leading to health risks from bacterial and viral infections associated with poorly managed waste. Furthermore, the shortage of trucks and workforce worsens the situation.”

Head of Sumur Batu Landfill:

“We emphasize the importance of economic and technological support in waste management. Reducing waste production and improving coordination and public awareness are essential to reduce pollution and health risks. Adding sufficient trucks and personnel would significantly improve waste management effectiveness.”

Staff (2) from the Environmental Agency:

“It is crucial to optimize Reuse, Reduce, and Recycle Waste Management Sites (R3WMS) and utilize modern technologies such as incinerators and Waste-to-Energy Plants. However, these technologies cannot be effectively utilized without adequate trucks and workforce.”

The shortage of trucks and human resources directly impacts waste collection and transportation rates, leaving most waste unmanaged and increasing public health risks and environmental pollution. Strategic steps to enhance infrastructure and operational capacity are essential. Bekasi City can improve its waste management effectiveness by implementing an integrated waste management hierarchy approach, including reduction, reuse, recycling, and modern processing technologies. However, success depends on meeting fleet and workforce requirements and increasing public awareness. These improvements reduce health risks and create a cleaner and more sustainable environment.

3.5.2. Community Participation

Community participation is essential to enhance the effectiveness of the waste management system. Low awareness and a lack of understanding about waste sorting remain significant barriers to policy implementation.

Waste policy expert from the university (1):

“Awareness of R3WMS principles remains low, indicating the need for more intensive socialization to increase community participation. Community-based programs such as Waste Banks can help improve awareness and engagement.”

Community member (7):

“The lack of community involvement in waste sorting is a major obstacle. Active participation is critical for successful waste management.”

Waste expert from the university (1):

“More intensive campaigns and educational programs are needed to increase public understanding of the health impacts of waste and proper management methods.”

3.5.3. Health Impacts of Poor Waste Management

Poor waste management in Bekasi City creates breeding grounds for disease vectors such as mosquitoes, flies, and rats, which spread infectious diseases like dengue fever, malaria, cholera, and leptospirosis.

Staff (5) from the Environmental Agency:

“We emphasize the importance of public education about hazardous materials and the need for active participation in waste management to reduce health risks.”

Waste Policy Expert from the University (2):

“Low public awareness about waste sorting and hazardous materials increases the risk of diseases such as salmonellosis and shigellosis.”

3.5.4. Policy Implementation: Quality and Coordination

Adopting Van Meter and Van Horn’s perspective on Policy Quality in Waste Management, the informants’ insights highlight a strong correlation between low public awareness and the health risks associated with improperly disposed waste. The effectiveness of waste management policies significantly depends on the quality of regulations, the adequacy of resource allocation, and the coordination between relevant agencies.

Head of the Regional Planning Agency:

“Effective waste management requires inter-agency coordination to ensure proper policy implementation. However, without public awareness and regulatory adjustments, the health impacts of poor waste management will persist.”

Staff (4) from the Environmental Agency:

“The limited number of collection vehicles and the overcapacity of Sumur Batu Landfill are major challenges. Expanding infrastructure and increasing budget allocation are necessary to improve waste management effectiveness.”

The interviews reveal that low public awareness, limited infrastructure, and inadequate inter-agency coordination are the primary challenges in waste management in Bekasi City. To address these issues, the following measures are needed:

1. Public Education and Awareness: Increasing awareness about waste sorting, hazardous materials, and the importance of active participation.

2. Infrastructure Optimization: Adding more garbage trucks, implementing modern technologies such as incinerators, and expanding landfill capacity.
3. Inter-Agency Coordination: Strengthening collaboration between local governments, the Environmental Agency, and communities to ensure effective policy implementation.
4. Policy and Budget Support: Allocating sufficient budgets to support sustainable waste management and reduce health impacts from unmanaged waste.

4. Discussion

4.1. Waste Management Hierarchy Theory

The Waste Management Hierarchy Theory provides a framework for prioritizing waste management practices to minimize environmental and health impacts. The hierarchy ranks strategies from most to least preferred: Reduction, Reuse, Recycling, Energy Recovery, and Disposal. An analysis of waste management in Bekasi using this theory highlights significant challenges and inefficiencies^[18].

Reduction—the most critical step—remains poorly implemented in Bekasi. Despite efforts by the Regional Planning and Environmental Affairs staff to improve coordination and budgeting, reduction initiatives are limited. Low public awareness and inadequate infrastructure are the primary barriers to reducing waste production^[19, 20]. Education campaigns to promote responsible consumption and waste minimization have not been effectively executed, leaving this foundational step underutilized.

- Reuse initiatives, which include programs like Integrated Waste Management Centers and Waste Banks, face similar issues. Public participation is low due to insufficient awareness and limited infrastructure to support these efforts. The current reuse programs fail to significantly reduce the reliance on disposal methods.
- Recycling efforts, although emphasized by the Head of Environmental Affairs and staff, are constrained by low community participation and a lack of public understanding about waste sorting. The absence of comprehensive waste sorting practices exacerbates inefficiencies in the recycling process, leaving much of the recyclable material unprocessed.

- Energy Recovery, involving technologies such as incinerators and Waste-to-Energy Plants, is seen as a priority for certain stakeholders. However, its success hinges on robust economic and technical support, which remains insufficient. Without the necessary investments and coordination, the potential of energy recovery to reduce landfill reliance and generate energy is not fully realized.
- Disposal is still Bekasi's primary waste management method, particularly in Sumur Batu. Landfill overcapacity and the resulting environmental impacts illustrate the inadequacy of this approach. With disposal being the least preferred option in the hierarchy, the heavy reliance on this method underscores the urgent need for more sustainable practices.

Comparatively, countries like Japan, Sweden, and Germany have advanced waste management systems. Japan excels with its strict adherence to the hierarchy, focusing on reduction, reuse, and recycling, minimizing disposal through effective sorting and recovery technologies^[21]. Sweden is noted for its high recycling rates and energy recovery, supported by advanced incineration and public solid policies^[22]. Germany's comprehensive system features detailed waste sorting and advanced recycling technologies backed by strict policies and high public awareness^[23].

- Implications for Bekasi City: The Bantar Gebang Landfill waste management system relies disproportionately on disposal, with limited progress in reduction, reuse, and recycling. Energy recovery, while prioritized, is less efficient than systems in countries like Sweden. Public awareness and education are notably insufficient, contributing to the challenges of implementing effective waste management practices. To improve, the Bekasi City Government can adopt strategies inspired by advanced systems:

1. Enhance Reduction Efforts: Promote campaigns to minimize waste production through responsible consumption and reduced packaging. Strengthen regulations and incentives for businesses and consumers to adopt waste-reduction practices.
2. Improve Recycling Programs: Develop comprehensive waste sorting systems and invest in recycling infrastructure. Public education cam-

paigns encouraging waste sorting and recycling can improve participation and efficiency.

3. Expand Energy Recovery: Invest in advanced technologies such as incinerators and Waste-to-Energy Plants. Ensure sufficient economic and technical support to optimize these systems.
4. Increase Public Engagement: Public awareness campaigns similar to those in Japan and Germany should be implemented to encourage participation in waste reduction, sorting, and recycling programs.

By learning from global leaders in waste management, Bekasi can transition toward a more sustainable system, reducing its reliance on landfills and addressing the environmental and health impacts of inadequate waste management.

4.2. Community Participation Theory and Comparison with Global Cities

Community Participation Theory highlights the critical role of public involvement in the planning and executing public policies, suggesting that greater community engagement leads to more effective outcomes^[24]. Applying this theory to Bekasi's waste management practices and comparing them with global examples reveals the significant impact of community participation on waste management effectiveness and public health.

In Bekasi, initiatives such as Integrated Waste Management Centers and Waste Banks are designed to engage residents in waste segregation and recycling. However, as highlighted by interviews with stakeholders from the Department of Environmental Affairs and the Regional Planning Agency, community participation remains inadequate. Low public awareness, coupled with insufficient outreach and education, hampers the effectiveness of these programs. Despite the intent to promote active involvement, the limited engagement undermines the success of these initiatives, leading to inefficient waste management practices and worsening environmental and health challenges.

In contrast, cities with successful waste management systems, such as Tokyo, Stockholm, and Berlin, demonstrate high levels of community participation. Tokyo's waste segregation system requires active resident involvement and is supported by extensive educational campaigns and clear guidelines, resulting in improved public compliance and reduced

health risks. Stockholm employs robust public engagement through community recycling centers and educational initiatives, which promote waste reduction and enhance waste management efficiency^[25]. Berlin's extensive outreach and educational programs encourage resident participation in waste segregation and recycling, leading to high recycling rates and effective waste management^[26].

Comparing Bekasi with these cities illustrates that strong community participation significantly influences successful waste management. Cities like Tokyo, Stockholm, and Berlin show that active public engagement leads to more effective waste management and better health outcomes. To improve its waste management system, Bekasi could benefit from adopting strategies used by these cities, including enhancing public education, increasing community involvement in policy planning, and making waste management systems more accessible.

4.3. Policy Analysis

Van Meter and Van Horn's Public Policy Implementation Model offers a framework to evaluate policy effectiveness by examining policy standards, available resources, inter-organizational communication, organizational characteristics, and implementer attitudes. Applying this model to Bekasi's waste management system reveals several critical issues and areas for improvement. In Bekasi, governance involves multiple stakeholders, including the Regional Planning Agency and the Department of Environmental Affairs. However, their coordination is often fragmented, which undermines policy effectiveness. To enhance policy implementation, Bekasi must strengthen its governance framework to ensure consistent application of standards across various government levels.

Resource constraints are a significant barrier to effective policy execution in Bekasi. The city faces financial limitations, inadequate infrastructure, and insufficient technological support. The underfunding of Integrated Waste Management Centers and the need for advanced technologies like incinerators impede waste reduction and recycling progress. Addressing these resource deficiencies is crucial for improving waste management outcomes. Effective communication between government agencies, local authorities, and waste management companies is essential for successful policy execution. Bekasi needs help with communication

gaps and coordination issues, which lead to inefficiencies. Improving these interactions and ensuring stakeholder alignment is necessary for cohesive policy execution.

The characteristics of implementing organizations also impact policy success. In Bekasi, agencies such as the Department of Environmental Affairs and the Final Disposal Site face limited capacity and technical expertise challenges. Underutilizing advanced technologies and inefficient operations indicate organizational improvements and capacity building. Lastly, the attitudes of implementers play a critical role. In Bekasi, varying levels of commitment and motivation among officials and waste management staff affect policy effectiveness. Enhancing motivation and public engagement in waste reduction and recycling programs is vital.

Bekasi can improve its waste management system by addressing governance issues, investing resources, enhancing communication, strengthening organizational capacity, and boosting implementer motivation. Lessons from advanced waste management systems in Japan, Sweden, and Germany can guide these improvements, leading to a more effective and sustainable waste management approach.

The analysis of waste management in Bekasi highlights several critical issues and their implications for health and disease. Ineffective waste management in Bekasi poses significant health risks. Poor waste segregation and a heavy reliance on disposal methods contribute to the spread of diseases. Unmanaged waste attracts vectors like rats and insects, leading to leptospirosis and dengue fever. Additionally, the open burning of waste and inefficient waste-to-energy processes release toxic pollutants, exacerbating respiratory and other health problems. Limited community participation worsens these health risks by impeding adequate waste segregation at the source. Without active residents' involvement, waste is not sorted correctly, increasing the likelihood of hazardous materials contaminating general refuse. This mismanagement leads to environmental contamination, including soil and water pollution, directly affecting health. For instance, improper electronic waste disposal can contaminate heavy metals, posing severe health hazards.

When efficiently implemented, recycling and energy recovery systems can help mitigate these health risks. Improved recycling practices and advanced technologies like high-efficiency incinerators reduce landfill waste and minimize harmful emissions. However, in Bekasi, the limited

effectiveness of these systems, due to insufficient community engagement and inadequate infrastructure, prevents them from fully realizing their potential health benefits. Enhancing these systems could significantly reduce environmental and health impacts.

Excessive reliance on final disposal methods, particularly in areas of Sumur Batu, generates additional health concerns. Poorly managed landfills produce leachate, a toxic liquid that contaminates groundwater and threatens drinking water sources. They also emit methane, a greenhouse gas contributing to climate change and associated health effects.

Comparing Bekasi with global cities such as Tokyo, Stockholm, and Berlin reveals how effective waste management practices can improve public health. These cities implement rigorous recycling programs, advanced energy recovery technologies, and strong community participation, leading to better health outcomes and reduced environmental impact^[27]. For example, Tokyo's advanced waste management system minimizes landfill use and reduces air pollution, benefiting public health.

The authors should discuss the results and how they can be interpreted from the perspective of previous studies and the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

This study offers important novel contributions compared to earlier research. First, community engagement is presented as an accessory and a key determinant of overall success in waste management systems. The study underlines proactive rather than passive participation, emphasizing public education, awareness, and active involvement. Second, it prioritizes health, linking ineffective waste management with various diseases. By highlighting conditions such as dermatitis and acute respiratory infections, the study underscores the need for preventive measures. Third, it recognizes the potential of modern technologies, including Waste-to-Energy and AI-based tracking, while stressing that institutional support and trained human resources remain crucial. This integrated perspective offers new pathways for sustainable waste management. Additionally, it contributes to broader discussions of public health policy.

5. Conclusions

The waste management challenges in Bekasi City highlight critical gaps in infrastructure, community participation,

and policy implementation, which collectively contribute to significant environmental and health issues. The reliance on final disposal methods, compounded by inadequate garbage truck fleets and a significant shortage of human resources, underscores the pressing need for systemic improvements. With 52% of uncollected waste, unmanaged waste has become a breeding ground for disease vectors, leading to respiratory infections, waterborne diseases, and other health conditions. Groundwater contamination and methane emissions from landfills exacerbate these risks, threatening public health and environmental sustainability.

At the same time, low public awareness and minimal community engagement further hinder the effectiveness of waste segregation and recycling initiatives. Programs such as Waste Banks and Integrated Waste Management Centers have failed to achieve their full potential due to insufficient outreach and limited public involvement. The lack of coordination among governmental agencies and inadequate policy enforcement further magnify these challenges. In order to address these issues, a comprehensive approach is necessary, focusing on enhancing infrastructure, fostering community participation, and strengthening policy frameworks. Bekasi can build a more sustainable waste management system by adopting best practices from cities like Tokyo, Stockholm, and Berlin. These cities demonstrate the importance of public education, advanced recycling, energy recovery technologies, and inter-agency solid coordination in creating effective waste management solutions.

Author Contributions

Conceptualization, D.M.; methodology, D.M.; software, D.M., B.H.P., and R.T.F.; validation, D.M., B.H.P., and R.T.F.; formal analysis, D.M., B.H.P., and R.T.F.; data curation, D.M.; writing—original draft preparation, D.M.; writing—review and editing, D.M., B.H.P., and R.T.F.; visualization, D.M., B.H.P., and R.T.F.; supervision, D.M., B.H.P., and R.T.F.; project administration, D.M.; funding acquisition, D.M. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This research was carried out with the approval of the University Ethics Committee No. 181-2023 and based on a Memorandum of Understanding between Universitas Pasundan, Bandung, and the Bekasi City Government, with written approval obtained from stakeholders.

Informed Consent Statement

Informed consent was not required for this study as it did not involve human participants.

Data Availability Statement

No new data were created or analyzed in this study. Data are already presented in this article.

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Conflicts of Interest

The authors reported no potential conflict of interest.

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