World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Innovate, educate, and transform: Tailoring sustainable waste handling solutions for Nepal's small populated municipalities – insights from Chandragiri municipality

Anil Kumar Baral *

Department of Management, Sikkim Professional University Sikkim, India.

World Journal of Advanced Research and Reviews, 2024, 22(01), 510–527

Publication history: Received on 01 March 2024; revised on 09 April 2024; accepted on 11 April 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.1.1128

Abstract

The research introduces a ground-breaking approach to waste management, emphasizing innovation, education, and transformation. Using Chandragiri Municipality as a case study, the study advocates a shift from traditional to progressive waste management strategies, contributing an inventive waste framework, sustainability advocacy, and a transformative blueprint. The waste composition analysis highlights Chandragiri's representative profile, leading to a comprehensive plan addressing challenges and recommending a transition to a profitable waste treatment model, supported by relevant statistics. The data-driven approach incorporates the official data of waste Composition from Chandragiri Municipality as secondary data and incorporates the primary data from Chandragiri households, ensuring a nuanced perspective. Discussions on implementation, viability, and environmental preservation underscore the dual benefit of sustainability. The study includes a comparative analysis, monitoring, and evaluation framework, examining international relevance and collaboration, and conducting a social and environmental impact assessment. The results indicate the necessity for inventive changes in Chandragiri's waste practices, recommending separate treatment centres at the ward level and Municipal level, composting machines, and a centralized waste treatment plant. Educational reforms involve revising school curricula and awareness campaigns. The transformation's success hinges on reducing waste size, efficient treatment centre operation, and ongoing public literacy. The conclusion summarizes key findings, envisioning a future with sustainable waste management practices deeply embedded in the community fabric.

Keywords: Compost; Education; Gasification; Innovation; MSW; Plasma-Pyrolysis; Sustainability; Shredder; Transformation; Trommel Machine; Treatment Centre

1. Introduction

The generation of waste persists as long as human civilization endures. The persistent challenge of waste generation in modern cities is heightened in Nepal, where local authorities grapple with the responsibility of waste management amid economic constraints (Sunil Herat and Cher Han Lau-2013). Solid waste management remains a significant environmental challenge in the country (ADB, 2013; Maharjan and Lohani, 2020; Pokhrel and Viraraghavan, 2005). According to Ravichandran and Venkatesan (2021), the adoption of sustainable and tailored waste management plans is imperative for cities and towns. Municipal solid waste management is a multidisciplinary activity that includes generation, source separation, storage, collection, transfer and transportation, processing and recovery, and, disposal (Rada et al., 2013, Bovea et al., 2010, Gallardo et al., 2015, Rada, 2014, Minoglou and Komilis, 2013, Wagner and Bilitewski, 2009). To develop a sound material-cycle society, a cost-effective integrated municipal solid waste management system is required for the municipalities (Weng and Fujiwara, 2011, Consonni et al., 2011, Massarutto et al., 2011, Ionescu et al., 2013, Eriksson et al., 2014).

* Corresponding author: Anil Kumar Baral

This article introduces a three-pillar philosophy: Innovate, Educate, and Transform, emphasizing the need to move beyond conventional concepts of reuse, reduce, and recycle. Drawing insights from Chandragiri Municipality in Nepal, the article discusses the waste profile, (Annex01) highlighting that organic waste constitutes 35%, rubber and leather combined 3%, textiles 15%, metals 1%, glass 8%, paper and paper products 7%, plastics 23%, and others 8%. Further waste profiles are categorized into only two segments as per the processing system (FIG NO AB-01): Re-valuable waste and Discardable waste. Organic matter prevalence in solid waste surpasses developed nations (Bhide and Sundersan, 1983), urging the conversion of organic matter to alleviate landfill burdens (Richard, 1992). Additionally, composting is endorsed as an effective method (Pokhrel and Viraraghavan, 2005). Chandragiri, with a population of 136,860 and 35,994 households, focuses on sustainable waste treatment centres, moving away from traditional landfill practices. Advocating for a zero-waste lifestyle, the article draws on primary data from wards (8, 10, and 15) and proposes ward-level waste treatment centres. Inefficient MSW collection, a global concern (Alam et al., 2008), necessitates machines and technologies within budgetary constraints, aligning with each municipality's waste profile. Education's role in empowerment is emphasized, proposing a curriculum shift to integrate waste handling in education up to the secondary level. Survey results suggest widespread support for such initiatives, potentially reshaping societal attitudes within 15 years. Effective communication for government policies, regulations, and waste handling methodologies is suggested to reduce waste at its source. The Transformation pillar advocates for periodic assessments of the waste management system, emphasizing continuous improvement through transformation analysis. In essence, this article lays the groundwork for exploring the three-pillar philosophy—Innovate, Educate, and Transform—as a strategy to revolutionize waste management in Nepalese municipalities. Subsequent sections will delve into practical application and potential impact, guided by insights from primary data in Chandragiri Municipality.

1.1. Significance of study

This research is of paramount significance as it addresses the multifaceted challenges of waste management, particularly focusing on Chandragiri Municipality in Nepal. The study introduces an inventive three-pillar approach—Innovate, Educate, and Transform—to pioneer progressive waste management strategies. It not only contributes a ground-breaking waste framework, advocates sustainability, and offers a transformative blueprint but also addresses the critical issue of a lack of experienced and trained manpower in Nepalese municipalities.

The challenges arise from the absence of accessible expertise within municipal teams, specifically in technological, environmental, and mechanical domains. The shortage of skilled professionals hampers the identification of suitable methodologies, selection of appropriate machines and technologies, and overall execution of efficient waste management practices. This study aims to serve as a valuable resource, providing references and insights to guide municipalities facing such challenges. It aspires to empower municipalities by offering accessible knowledge and facilitating informed decision-making, especially in the absence of readily available experienced human resources and experts.

1.2. Statement of problem

Chandragiri, much like Kathmandu Valley, transports its waste to the Banchare-danda landfill site as it lacks its own landfill or treatment centre. This mirrors the situation in many municipalities that grapple with similar challenges, highlighting a widespread issue in waste management practices.

Contemporary waste management in Chandragiri faces significant hurdles rooted in conventional approaches. The primary challenge lies in finding suitable sites for treating the Municipal Solid Waste (MSW) generated within Chandragiri, a formidable task for the local governing body. The problem originates from the collection pattern and system, where openly loaded trucks follow an unsanitary and inefficient collection method. Waste workers along roadsides are compelled to sort mixed waste due to the absence of proper sorting mechanisms and an organized waste management plan. To progress toward a sustainable material-cycle society, municipalities, including Chandragiri, require a cost-effective integrated municipal solid waste management system (Weng and Fujiwara, 2011; Consonni et al., 2011; Massarutto et al., 2011; Ionescu et al., 2013; Eriksson et al., 2014). Globally, solid waste collection constitutes a significant portion of expenditure on waste management (Jacobsen et al., 2013), with collection costs representing a substantial proportion of municipal solid waste management budgets in low and middle-income countries (Aremu, 2013). Waste collection and transportation problems are acknowledged as some of the most challenging operational issues in developing an integrated waste management system (Nuortio et al., 2006). The reliance on traditional waste management methods, coupled with a shortage of experienced and trained manpower, raises environmental, economic, and social concerns. Ineffective waste practices, exacerbated by a lack of expertise, contribute to heightened waste accumulation, insufficient treatment, and the potential for environmental degradation. Additionally, there is no one-size-fits-all treatment system suitable for all waste fractions (Liamsanguan and Gheewala, 2008), necessitating the integration of appropriate treatment methods, such as recycling, anaerobic digestion, incineration, and landfilling, for proper, balanced MSW management (Tabata et al., 2011; Bahor et al., 2009; Hoornweg and Bhada-Tata, 2012). This comprehensive approach is known as integrated solid waste management (ISWM), encompassing the recovery of useful materials and energy from waste (Kathiravale and Yunus, 2008; Menikpura et al., 2012a). The development of ISWM requires not only the integration of technologies but also the formulation of policies and programs essential for managing waste streams (Koroneos and Nanaki, 2012).

This statement of the problem underscores the urgent need to shift from conventional to innovative and sustainable waste management practices. It emphasizes the critical requirement for accessible knowledge and expertise within municipality teams to effectively address the complex challenges associated with the current waste management system.

Figure 1 Categorization of waste according to processing

Objectives of study

- **Innovate**

a) Introduce inventive waste management strategies and methodologies tailored to the specific needs of Chandragiri Municipality and other municipalities with similar characteristics. This includes identifying public preferences regarding the location of waste treatment centres.

b) Explore and propose a ground-breaking waste management framework aimed at enhancing efficiency and effectiveness, considering the insights gathered from public preferences in waste treatment centre locations.

- **Educate**

Advocate for a revolutionary shift in academic curriculum design, incorporating waste handling techniques, civilizational aspects, and source waste reduction up to the secondary level.

Propose awareness campaigns and educational reforms to instil a sense of responsibility and promote a cultural shift toward sustainable waste management practices.

- **Transform**

Advocate for the establishment of waste treatment centres at the ward level rather than the municipal level, based on primary data analysis from specific wards (8, 10, and 15).

Emphasize the incorporation of machines and new technologies within budgetary constraints, aligned with the unique waste profile of each municipality.

Call for periodic assessments of the waste management system, promoting continuous improvement and the adoption of new techniques in treatment centres.

- **Capacity Building**

Emphasize the importance of capacity building within municipal teams, advocating for the establishment of expert foundations and collaborative teams encompassing civil, environmental, mechanical, and other relevant domains.

- **Knowledge Transfer**

Facilitate knowledge transfer through the dissemination of best practices, methodologies, and technological solutions that can be applied by municipalities with limited access to experienced human resources.

- **Human Resource Development**

Promote the development of human resources in municipalities by encouraging the formation of skilled teams capable of identifying suitable waste management methodologies and technologies

- **Expertise Accessibility**

Highlight the accessibility of expertise through the insights provided in this journal, enabling municipalities to overcome challenges associated with the lack of readily available experienced professionals. By addressing these objectives, the study aims to contribute not only to inventive waste management practices but also to the empowerment of municipalities dealing with resource constraints in terms of experienced and trained manpower.

- **Implementation Viability:**

To assess the viability of the proposed waste management strategies, considering factors such as waste reduction, efficient treatment centre operation, and Public Engagement and Preferences. This includes exploring the public's views on the optimal level (ward, municipal) for the placement of treatment centres and their readiness for waste segregation at the source.

1.3. Hypothesis

- **Null Hypothesis (H0):** There is no significant difference in the preference among the public for locating waste treatment centers at the ward, municipal, or community levels.
- **Alternative Hypothesis (H1):** The public exhibits a significant preference for locating waste treatment centers at the ward level compared to the municipal and community levels.

Table 1 Contingency

	Ward	Municipal	Community
Observed Frequencies	50	49	19

We compute expected frequencies under the assumption of the null hypothesis, which states an equal distribution of preferences among the categories. Expected frequency for each category is given by:

$$E=\frac{(T \times C)}{N}$$ *Where: (T) is the total number of observations, (C) is the total number of categories, (N) is the total number of respondents*

1.3.1. Expected Frequencies

In this case, the expected frequency for each category is: E= (119×1)/3=39.67

To test the hypothesis, we use the chi-square test statistic formula

$$\chi 2=\frac{\sum(O-E)^2}{E}$$ *Where: - (chi² χ2) is the chi-square test statistic, -(O) is the observed frequency, - (E) is the expected frequency*

1.3.2. Chi-Square Test Statistic

Chi -Square test statistics is approximately $\chi 2$=15.66

1.3.3. Determine Degrees of Freedom

The degrees of freedom (df) for a chi-square test of independence in a contingency table are calculated using the formula: df = $(r-1)\times(c-1)$

In our case:

- We have one row in the contingency table (representing the levels: ward, municipal, and community).
- We have three columns in the contingency table (representing the count of respondents preferring each level).

So, applying the formula:

df = (3−1) × (3−1) =2×2= 4

Therefore, the degrees of freedom for this chi-square test are 4.

Based on the degrees of freedom (df) of 4 and the calculated chi-square test statistic of approximately 15.66, we compare this value to the critical value from the chi-square distribution table at a given significance level (e.g., 0.05). Since the degrees of freedom is 4, we look up the critical value in the chi-square distribution table for a significance level of 0.05 and 4 degrees of freedom. Let's assume that the critical value is 9.49 for this significance level and degrees of freedom. Since the calculated chi-square value of 15.66 exceeds the critical value of 9.49, we reject the null hypothesis.

Therefore, we conclude that there is a significant difference in preferences among the public for locating waste treatment centres at the ward, municipal, or community levels.

1.3.4. Waste Profile (Chandragiri as Symbolic Representation)

Chandragiri Municipality is a symbolic representation of 32 municipalities in Nepal having a population between 100000 to 200,000. The total Waste of Chandragiri is 28 Tons/day, and waste is 0.80 Kg/HH/Day. The population number is may be one factor of similarities amongst the municipalities, even though we can observe many similarities in the waste profile amongst such municipalities let us compare between Chandragiri and Kirtipur municipalities, geographically these are connected to each other, and these two municipalities have many similar characteristics, like they are inside the Kathmandu valley Bordered with Kathmandu metropolitan city, both consist of hill and progressing towards societal development and accepting migrants from others part of the country.

Table 1 Comparative analysis of waste profile, Kirtipur and Chandragiri Municipality

Waste Types	**Chandragiri**	**Kirtpur**
Organic	35%	44%
Plastic	23%	13%
Metal	1%	Na
Glass	8%	10%
Cloth	15%	Na
Electronic	Na	Na
Rubber	3%	9%
Paper	7%	11%
Hazard	Na	7%
Bio Medica	Na	Na

Construction	Na	Na
Other	8%	6%
Total	100%	100%

Source: Solid waste composition and its management: A case study of Kirtipur Municipality-10, Prakash Awasthi, Gopi Chataut, Ram Khatri

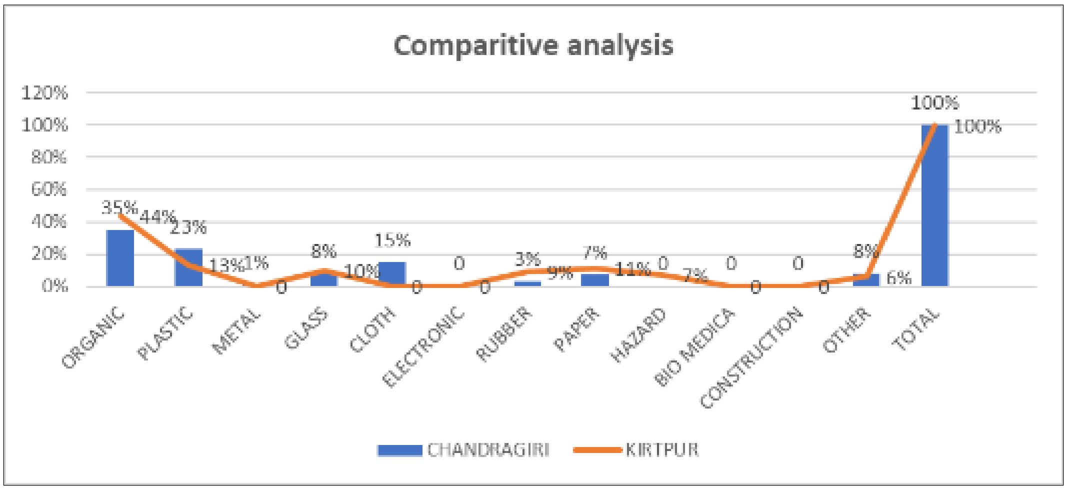

Figure 1 Graphical representation of Comparative analysis of waste profile, Kirtipur and Chandragiri Municipality

2. Methodology

2.1. Data Collection

The combination of both qualitative and quantitative approaches where primary data collection through surveys, interviews, and on-site observations will provide a comprehensive understanding of the public's sentiments, expert opinions, and the practical aspects of waste management in Chandragiri.

2.1.1. Primary Data

Conduct surveys and interviews with residents of Chandragiri Municipality in wards 8, 10, and 15. Target at least 100 respondents to gather insights into their waste disposal habits, awareness levels, and opinions on potential changes.

Develop a concise one-page questionnaire comprising 5-6 questions to be administered to the general public. The questionnaire aims to gauge the general opinion about waste management and the willingness to embrace potential changes. The Research question also tries to identify the public preference for the location for the treatment center.

2.1.2. Field Observations

Conduct on-site field observations to closely examine the existing waste management practices in Chandragiri Municipality.

Pay special attention to collection methods employed, segregation practices at source, transportation processes, and the condition of existing treatment facilities.

Document observed practices and note any challenges or inefficiencies in the current waste management system.

2.1.3. Waste Composition Analysis

Collaborate with waste management experts to conduct a detailed analysis of the composition of waste in Chandragiri. Use this information to understand the types and proportions of different waste materials generated.

2.1.4. Comparative Analysis and Expert Consultations

Compare waste management inventive practices with a sustainable approach. Consulting about the technology and ROI with waste Manufacturing machine Manufacturers in Nepal, India or foreign countries.

Evaluate the financial and logistical feasibility of implementing proposed waste management strategies. Assess the availability of resources, technologies, and skilled manpower required for successful execution.

Engage with experts in waste management, environmental science, and sustainable development to gain insights into best practices, suitable technologies, and potential challenges in implementing transformative waste management.

2.1.5. Education Impact Assessment

Develop surveys and assessments to measure the impact of proposed educational reforms. Gather data on changes in awareness, knowledge, and behaviour related to waste management among the local population.

2.1.6. Transformation Analysis

Design a framework for periodic assessments of the waste management system. Implement transformation analysis to measure the effectiveness of the proposed changes over time and identify areas for improvement.

2.1.7. Stakeholder Engagement

Engage with local government officials, waste management authorities, residents, and educational institutions in Chandragiri. Seek their input, address concerns, and build a collaborative approach toward implementing inventive waste management practices.

2.1.8. Documentation and Reporting

Compile all gathered data, analyses, and findings into a comprehensive report. Clearly outline the proposed inventive waste management framework, educational reforms, and transformation plan. Provide recommendations for effective implementation and continuous improvement.

2.2. Public Attitudes: Embracing Solutions and Decentralization

The data chart below (Annex .03) indicates that the public in all three wards is highly positive about participating in waste management training and being aware of policies. Similarly, the public is highly accepting and ready to segregate waste if the municipality provides solutions. However, there is a mixed opinion on whether the treatment centre should be decentralized at the ward level or centralized at the municipal level. Based on this, we have proposed both types of machines and technology in the innovation section. In conclusion, it is evident that Chandragiri's public is keen on having a waste processing centre.

2.3. Innovate: Pioneering Sustainable Waste Management Solutions

Addressing waste management in Chandragiri necessitates inventive solutions due to the diverse mix of materials, predominantly biodegradable waste, followed by significant amounts of plastic and textiles. Drawing guidance from notable waste machine manufacturers *like "SMS-Hydrotech", Faridabad; "Paryawaran Kawach", Delhi; "BL Engineering", Gujarat; and "Convotec-Engineering", Gujarat,* our focus is on practicality.

Primary data indicates (annexe: public willingness to segregate waste at the source, prompting us to consider both scenarios. If source segregation is achieved, our initial phase aims to collect organics, recyclables (Plastic, Rubber, Paper, and textiles), metals, biohazard waste, and glass separately, recognizing the challenges of full source segregation. Further refinement occurs at treatment centres, and this two-step approach, from collection to creating final saleable products, offers a practical and comprehensive solution. The insights gained from consultations with manufacturers inform our strategy, fostering sustainable waste management practices in Chandragiri, with no endorsement of whole waste incineration in this article.

There are two methods for organic waste management

- Generating Compost/manure
- Generating Bio Gas

2.4. Making Compost/manure from the organic waste

This article places a primary emphasis on inventive composting methods, sidelining traditional backyard techniques like open-air composting and direct composting. Highlighting recent approaches, such as tumbler composting and worm farm composting (vermicomposting) utilizing effective microorganisms (EMO), the focus shifts towards mechanical composting. Mechanical composting, using machinery to expedite the process, becomes the central theme.

This method proves particularly beneficial at both ward and municipal levels, allowing for efficient composting without significant human expertise. Operating with unskilled labour, these machines, requiring minimal space and infrastructure, offer a rapid 24-hour composting cycle using raw materials like sawdust, dry leaves, or chicken farm waste. “This electric-operated machine boasts a primary component, the shredder, designed to efficiently process a variety of raw materials, including food waste, vegetable waste, and meat by-products, such as bones.

After the initial shredding, the waste moves into the main chamber, where a continuously rotating unit facilitates the organic waste's movement. Within this chamber, the waste is subjected to controlled heating, reaching specific temperatures. Remarkably, this accelerated process results in the development of high-quality compost within a remarkably short timeframe—typically 20 to 24 hours."

2.5. Ward level Distribution approach

Embracing decentralization offers significant advantages, particularly in the context of waste management (FLOWCHART AB 01). The diverse array of available machines allows for a distributed approach, even at the ward level. Consider a scenario where the total organic waste generated is 10 tons, distributed across 15 wards. By allocating machines capable of handling 700-750 kg of waste per day to each ward, the decentralized model facilitates the conversion of organic waste into compost locally. In this setup, each ward is expected to treat approximately 700 kg of organic waste daily. By deploying 700-750 kg capacity machines in each ward, a sustainable solution is achieved. These machines can efficiently convert organic waste into compost, providing a decentralized and community-driven approach to waste management.

2.6. Municipal Level approach

As an alternative, one could opt for a centralized approach by establishing a 10-ton organic waste-to-compost-making plant at the municipal level (FLOWCHART AB 01). However, the decentralized model proves advantageous as it not only addresses the waste issue at the source but also fosters community involvement in sustainable waste management practices.

2.7. Commercial composting without source segregation

Commercial composting without source segregation, while not ideal, can be a practical solution for municipalities facing challenges in waste management. The key lies not only in composting itself or treating the waste but also in fostering behavioural changes and instilling new habits. Municipal Solid Waste (MSW) plants equipped with waste processing machines play a crucial role in handling daily fresh waste, legacy waste, and bio-mining processes. (Annex:05)

MSW plants utilize machines like waste shredders to break down fresh waste, trommel screens for screening and recycling useful products, and other equipment such as baling machines, material handling conveyors, sorting conveyors, waste grinders, air blowers, and magnetic separators. In this process, loaders like JCB place municipal solid waste in the machine input area for segregation.

The organic waste, sized less than 100 mm, undergoes a 30–35-day composting process. Afterwards, it passes through a trommel machine to filter for 35-mm, 16-mm, and final 4 mm fine organic waste, which is then ready for sale. Approximately, 10 tons of waste per day can yield around 0.2 tons of compost daily.

On the other hand, the machine segregates plastics, textiles, and papers, as well as metals and glasses. Further sorting and processing can be applied to these materials, such as shredding and extruding plastics for sale, grinding glasses for various applications, or using glass dust in construction.

2.8. Machines for further treatment

- Plastic Shredder /Extruder/Pulveriser
- Glass Grinder
- Fabric shredder

2.9. Incineration or Pyrolysis Plant for Bio-Hazardous Waste – Dead Animals.

In Chandragiri's data, the 8 per cent categorized as "others" may indicate undefined waste, including biomedical, hazardous waste, and dead animals. Small municipalities can consider a smart, environmentally friendly hazardous waste cum animal crematorium, incorporating technologies like gasification and a fully environmentally friendly plasma pyrolysis plant, ensuring zero emissions **(Annex:06)**. This advanced technology ensures minimal ash collection and plasma pyrolysis is the only process that effectively destroys waste in the absence of oxygen. The plasma machines are designed in such a way that all hazardous waste can be treated or destroyed without human interference. Moreover, healthcare facilities in the municipality are equipped with autoclaves and sterilization units for the proper disposal of hazardous waste, contributing to an efficient and environmentally friendly waste management system. Strict adherence to biomedical waste disposal rules adds an extra layer of responsibility and safety, ensuring that only waste requiring destruction or incineration is sent to treatment centres, thereby promoting sustainability in waste management.

2.10. BIO-GAS from the Bio-Degradable (Organic) waste

The bio-gas production process from organic waste is a machine-driven innovation designed to efficiently manage various organic materials, such as food scraps and vegetable waste. Initiated by the acceptance of these materials into the machine, which often includes a shredder as its primary component, the waste undergoes a transformative journey. The shredder breaks down the organic waste into smaller particles, preparing it for the subsequent stage. These shredded particles then enter a fermentation chamber, where anaerobic bacteria thrive in an oxygen-deprived environment. In this controlled setting, the bacteria play a crucial role in breaking down organic matter, yielding methane-rich bio-gas as a valuable by-product. This bio-gas, once collected, stands as a renewable energy source that can be effectively utilized for cooking, heating, or generating electricity. This eco-friendly process not only addresses the challenge of organic waste management but also transforms waste into a valuable resource, promoting sustainability and resourceful waste management practices.

However, despite its numerous benefits, the bio-gas production process is not without its challenges. One notable disadvantage is the potential for operational costs associated with the machinery, including initial setup expenses and ongoing maintenance. Additionally, the variability in organic waste composition and the need for efficient waste sorting present complexities in ensuring consistent and high-quality biogas production. Another consideration is the potential release of odours and emissions during the fermentation process, necessitating measures to address environmental and public health concerns.

3. Comparative analysis –Bio Gas Vs Organic Waste

3.1. The Comparative Chart as provided by "Paryabaran Kawach "– A Manufacturer of Biogas Plant – Delhi is attached to the annexure -4

In the provided comparative analysis data, there's a note expressing caution about the appropriateness of biogas, suggesting the need for further in-depth research before proceeding with a bio-gas project,

3.1.1. Educate

The Solid Waste Management Act of Nepal in 2068 empowers local authorities to handle solid waste.

At the national level, the federal government has introduced the Solid Waste Management National Policy 2022. This policy aims to ensure citizens' right to live in a clean and healthy environment by promoting effective waste management.

The act emphasizes the crucial role of local communities in waste management. It encourages them to build a robust database through research on waste management, and it also highlights the importance of enhancing the capabilities of agencies and stakeholders involved in waste management efforts.

Furthermore, the act strongly advocates for incorporating waste management topics into school curricula. This means that students will learn about proper waste management as part of their education.

Our survey reveals that most people in Chandragiri municipality don't know about the waste management policy. To address this, we should organize large-scale awareness campaigns and self-discipline classes in the community. These classes would focus on teaching people how and why to separate waste from its source. The role and involvement of the public in waste management. The community welfare. Volunteering, social service, code of conduct, and legal pathways may be included in the class. The local hands, NGO. Chamber of Commerce and Industries, Volunteering organizations, and health workers may be the partner organizations for mass education.

Interestingly, our survey also shows that the public is enthusiastic about joining such classes, especially if they are organized by local government or councils.

It's crucial to educate students about waste management through improved curricula. Schools can have classes discussing different waste management techniques, emphasizing their practical importance in daily life. It's essential to evaluate and reinforce this learning.

Education plays a crucial role in our community waste management plan. While technology addresses current issues, education is the key to achieving long-term goals.

3.1.2. Transform

The process of transformation revolves around proper assessment. Evaluating our ten-year plan and achievements involves comparing what we envisioned for effective waste management against our actual accomplishments. Positive transformation can be gauged both theoretically and practically.

Education is a key catalyst for change, significantly reducing waste. A lower proportion of plastic bags in the environment serves as an indicator of the success of educational efforts. The cleanliness of our city and county roads reflects the effective implementation of policies in the public domain and the success of awareness programs.

Monitoring how we handle waste under today's technology is essential. The use of sustainable technology is crucial, and our commitment to self-improvement is evident in the timely adoption of technological updates in treatment plans. This serves as a reliable indicator of our transformation journey.

In the realm of transformation, it's essential to keep an eye on the latest global technologies, even if our current financial situation doesn't allow immediate adoption. Being prepared and updated for the future is key, especially considering potential changes in our waste profile. The rise in electronic waste and the decrease in organic waste can impact our existing plans and infrastructure. Embracing a transformative approach means regularly evaluating our waste profile, upgrading our systems, and being adaptable to change.

Moreover, education and curriculum need adjustments to align with shifts in human behaviour,

urbanization, and the growth of corporate life. It's crucial to creatively assess societal changes, understand the nature of waste and its different categories, and continuously update rules, regulations, and policies. This ongoing process defines the transformative assessment needed for effective waste management. Certainly! Here's a merged version that condenses the content for a more streamlined presentation:

4. Results and discussion

4.1. Waste Composition and Challenges

The waste profile of Chandragiri Municipality reveals a diverse composition, with organic waste at 35%, plastics at 23%, and other categories contributing varied percentages. Tailored waste management strategies are needed to address the specific nature of the waste stream.

4.2. Inefficiencies in Current Practices

The existing waste management system is characterized by open-loaded trucks and a lack of organized plans, leading to environmental, economic, and social concerns. Roadside waste sorting indicates inefficiencies that need attention.

4.3. Support for Educational Reforms and Public Engagement:

Widespread support for educational reforms is observed, including the integration of waste-handling techniques in school curricula. Despite a lack of awareness about the waste management policy, the public shows enthusiasm for joining awareness campaigns and self-discipline classes, reflecting a willingness to actively participate.

4.4. Advocacy for Localized Waste Management

Advocacy for a shift towards ward-level treatment centres is based on primary data analysis from specific wards. This suggests a more localized approach to waste management, considering factors such as quantity, equipment types, transportation distances, and labour requirements.

4.5. Importance of Expertise Accessibility and Viability Assessment

The study emphasizes the significance of expertise accessibility, especially in the absence of experienced manpower. It underscores the need for capacity building, knowledge transfer, and the establishment of expert foundations. Additionally, a call for an assessment of proposed waste management strategies, considering factors like waste reduction, efficient treatment centre operation, and public engagement preferences.

4.6. Human Resource Development and Continuous Improvement:

The promotion of human resource development in municipalities is highlighted, focusing on forming skilled teams for waste management methodologies and technologies. The transformation pillar emphasizes the need for periodic assessments, promoting continuous improvement, and adopting new techniques in treatment centres.

5. Conclusion

The findings and results collectively suggest that a comprehensive three-pillar approach—Innovate, Educate, and Transform—can serve as an effective strategy to revolutionize waste management practices in Nepalese municipalities. The study not only identifies key challenges in the current waste management system but also proposes actionable solutions, emphasizing the importance of education, innovation, and ongoing transformation. The community's enthusiasm for educational reforms and awareness campaigns, coupled with the advocacy for ward-level treatment centres and expertise accessibility, provides a foundation for sustainable and impactful waste management practices. The conclusion envisions a future where these strategies are deeply embedded in the community fabric, fostering a culture of responsible waste management in Chandragiri Municipality and similar regions.

Recommendation

To address Chandragiri Municipality's waste management challenges, re-evaluating existing waste data is crucial for a reliable foundation. Urgent reforms within waste management teams at both council and ward levels are essential for enhanced data collection and practices. A systematic approach involves gathering preliminary ward-level data to refine waste management strategies. Enlisting an external technical team or consultant for research, considering budget constraints and environmental conditions, further enhances the process. Collaboration between academicians and waste management experts can lead to a simple curriculum for widespread education on proper waste management. This multifaceted approach aims to rectify data discrepancies, strengthen capabilities, and promote community awareness for a sustainable waste management system in Chandragiri Municipality.

Compliance with ethical standards

Acknowledgements

I extend my heartfelt gratitude to Mrs. Bhadra Aryal, Head of Environment at Chandragiri Municipality, for her unwavering support and guidance throughout the preparation of this article.

Special thanks to Mr. Ghanshyam Luitel and Mr. Shiva Maharjan, Ward Chairpersons of Ward 15 and Ward 10 respectively, of Chandragiri Municipality, for their generous cooperation for data collections in their wards.

I am deeply grateful to Dr. Bidhur Dhungel for his exceptional support and mentorship, which greatly contributed to the success of this journal article and research work.

I also wish to acknowledge Mr. Surya Bikram Singh, Managing Director of SMS Hydrotech India, Mr. Mahabir Suthar, Director of BL Engineering, and Mr. A.K. Mehta, representative of Prayawaran Kawach India, for providing their valuable insights and expertise during the preparation of this article.

Their contributions and encouragement have been instrumental in shaping the outcome of this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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Annexure: 01

Waste Profile of Chandragiri-Tons/day

Table 1 Waste Profile (Waste – Segregation)

CHANDRAGIRI MUNICIPALITY -WASTE PROFILE FISCAL YEAR 2024/25 AD							
BIO DEGRADBLE (ORGANIC)	RUBBER AND LEATHER	TEXTILES	METALS	GLASS	PAPER AND PAPER PRODUCT	PLASTICS	OTHERS
35	3	15	1	8	7	23	8

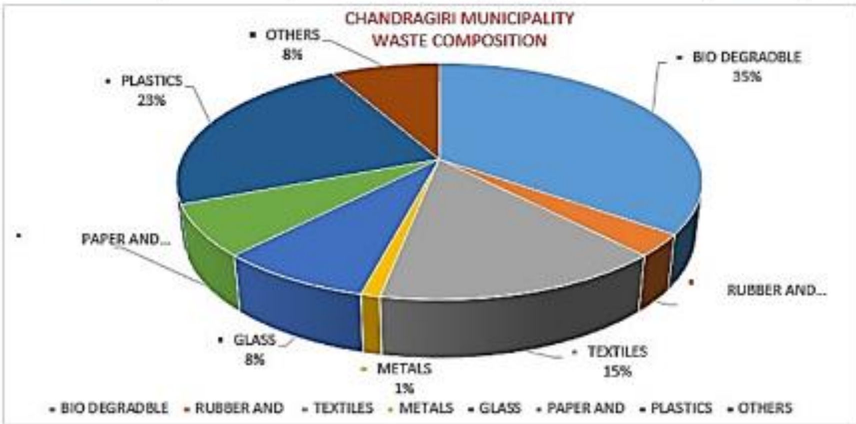


Table 2 Population Vs Waste Statistic

Population (x1000)	House hold (x1000)	Total Waste -per day (ton)	Waste- house hold /day (kg)
136.86	35.994	28	0.81

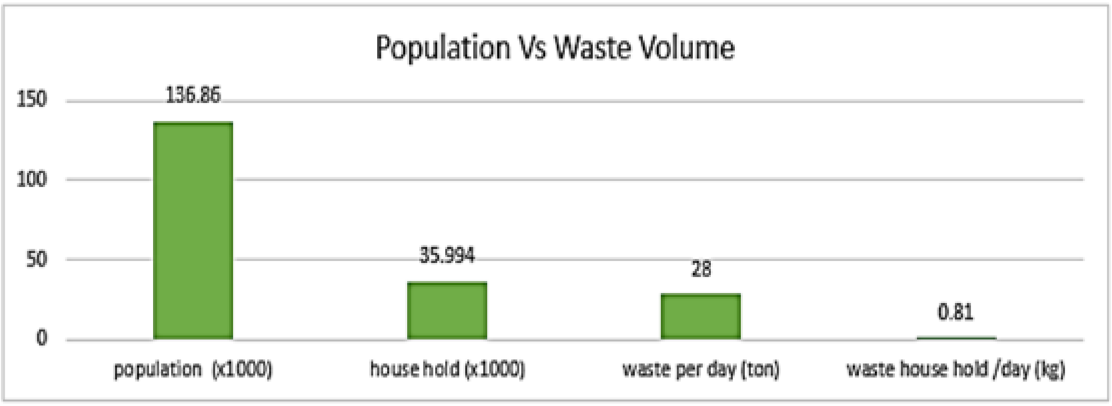


Figure 1 Graphical representation of Population Vs waste volume

ANNEXURE: 02

Table 3 Waste Profile on Mass Per day(Ton/Kg)

BIO DEGRADBLE	RUBBER AND LEATHER	TEXTILES	METALS	GLASS	PAPER & PAPER PRODUCT	PLASTICS	OTHERS
9.80	0.02	4.20	0.28	2.24	1.96	6.44	2.24
9800	24.3	4200	280	2240	1960	6440	2240

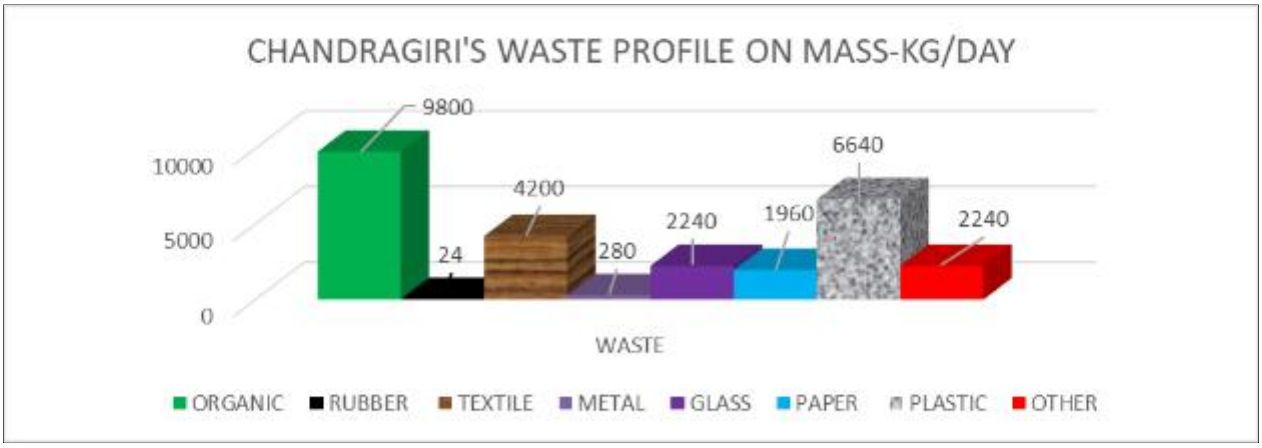


Figure 2 A –Graphical representation of Waste Profile on Mass Per day(Ton/Kg)

Annexure: 03

Table 4 Primary Data Analysis

GENDER		QUALIFICATION	
Male	Female	Secondary	51
59	60	Higher Secondary	22
		University	35
		NA	11

Table 5 Questionnaire format to identify the Public Opinion

S,N	QUESTIONS	NOS OF RESPONDENT AT CHANDRAGIRI MUNICIPALITY				TOTAL NO OF RESPONDENTS
		WARD NO 10	WARD NO 8	WARD N0 15		119
		38	40	41		
1	a vehicle having segregated chambers comes for waste collection	Excellent	Better	Good	Bad	
	TOTAL OF THREE WARDS	79	28	11	1	119
2	Possibilities to store the segregated waste at source and to give segregated waste to the collector, only when the collection truck comes	possible (Yes)	Not Possible (No)	-		
	TOTAL OF THREE WARDS	109	10			119
3	Treatment centre at which level is most appropriate in your opinion	Big municipal level	small ward level	smaller community level		
	TOTAL OF THREE WARDS	49	50	19		118
4	Up to which level the waste management subject should be made compulsory as an Academic curriculum	Primary school level	secondary school level	upper Secondary level		
	TOTAL OF THREE WARDS	22	50	47		119
5	Your Interest on the Presence of program related to waste management's Law/regulation etc.	Yes (Interested)	No (Not Interested)	Can-t say Right Now		
	TOTAL OF THREE WARDS	102	1	16		119
6	Are you aware of Rules and regulation and Laws /Policy about Waste Management of Nepal	yes	No			
	TOTAL OF THREE WARDS	22	57			79

Annexure: 04

Return of Investment

Table 6 Comparative Analysis: Bio Gas vs composting

BIO GAS					
Sl. No.	Item Description	Unit	Qty	Rate	Amount
1	10 TPD ORGANIC Municipal Solid Waste (To be used for Biogas)	Ton	10.0	₹ 19,50,000.00	₹ 5,85,00,000.0
2	Operational & Marketing Cost per tonne per annum	Ton	10.0	₹ 18,00,000.0	₹ 1,80,00,000.0
3	Civil Work				₹ 13,00,000.0
	Total Cost				₹ 7 ,78,00,000.00
3	Space Required				5000 Sq.ft.
4	Equipment				
	a. Shredder				
	b. Mixer Grinder				
	c. Biogas Storage Balloon				
	d. Biogas Generator				
4	Output				
	Gas per day		300.00	₹ 80.0	₹ 24,000.00
	Gas per annum				₹ 86,40,000.00
	Slurry per annum	Liter	21,60,000.0	₹ 2.0	₹ 43,20,000.00
	Return on Investment (Years)	8.05		10,43,28,000.00	
			NPR	166924800	

Table 6(A) Conversion of Organic waste in compost

ORGANIC- WASTE TO COMPOST					
Sl. No.	Item Description	Unit	Qty	Rate	Amount
1	700 - 750 Kgs Organic Waste Converter	No.	15.0	₹ 15,00,000.0	₹ 2,25,00,000.0
2	Operating Cost per annum	No.	15.0	₹ 25,000.00	₹ 45,00,000.00
3	Civil Work	N0.	15.0	₹ 3,00,000.0	₹ 45,00,000.00
	Total Cost				₹ 3,15,00,000.00
3	Space Required				200 Sq. Ft each
4	Organic Waste Converter				
5	Output				
	Compost per day	1,575.00		₹ 20.00	31,500.00
	Compost per annum				1,13,40,000.0
	Return on Investment (Years)		3.0		3,40,20,000.0
				NPR	54432000

Annexure: 05

Flow Chart: AB 02 Flow Cycle for Fresh Waste Processing

Commercial Composting & Segregation (LEGACY WASTE

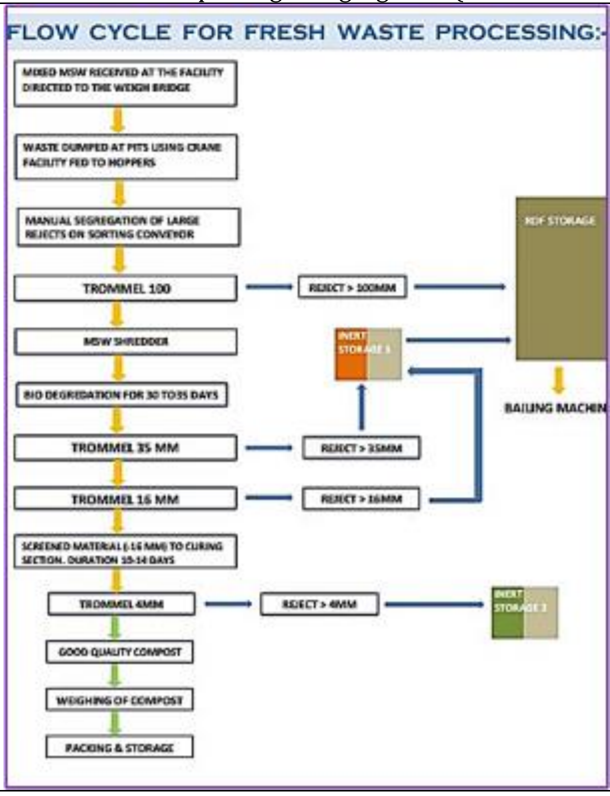


Figure 3 Trommelling machine segregating waste on landfill

Annexure 06

Image No 02 Organic Waste to compost Machine –set up

PIC: SMS HYDROTEC -INDIA

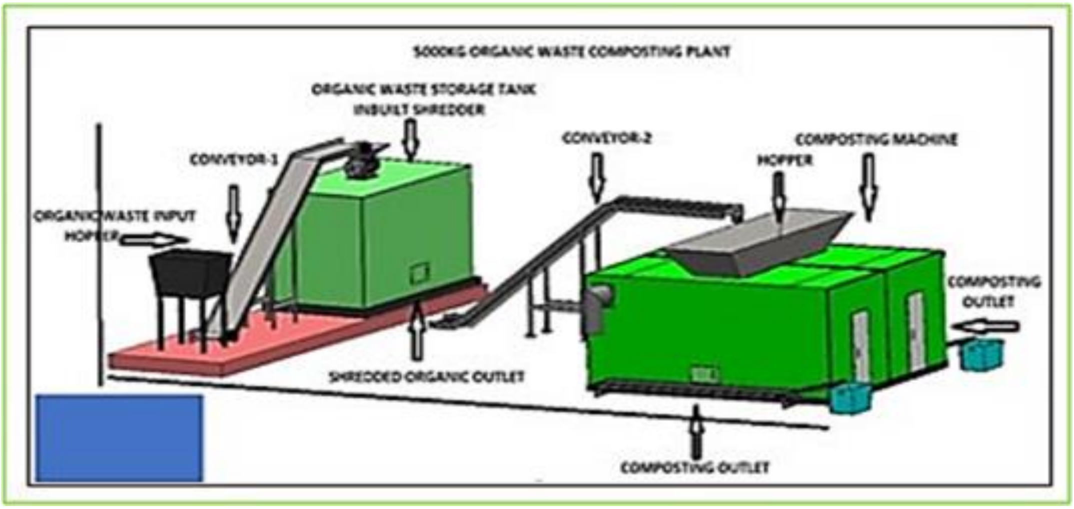
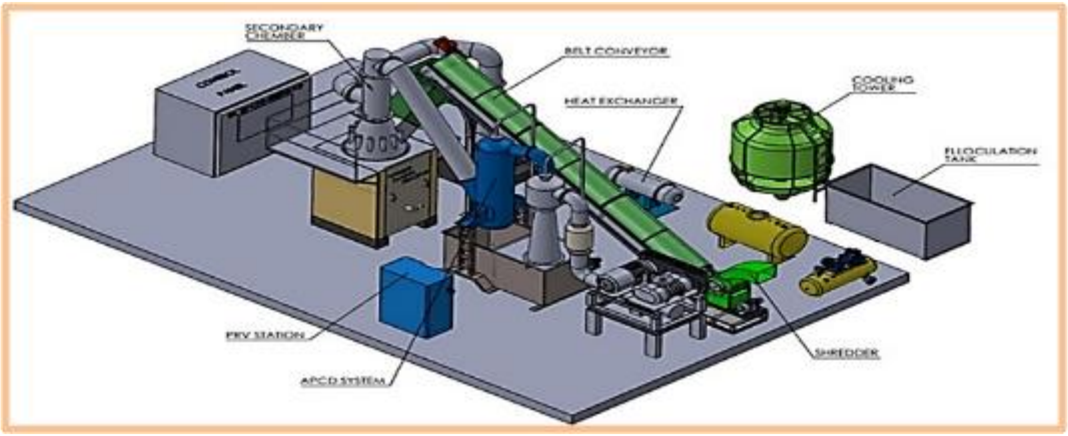


Figure 4 Bio Gas Machine –set up

Figure 5 Plaza Pyrolysis -Set Up: Picture BL Engineering



(Source B.L Engineering-India)