Opportunities for Organic Waste Valorization to Promote a Circular Economy in Nepalese Municipalities

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Abstract: Nepal generates high organic waste volumes, requiring circular solutions. This paper presents a multi-scale framework integrating household composting, community co-composting, and large-scale CBG plants. Case studies show effective waste reduction, quality compost production, and viable biogas generation. The approach enhances resource recovery and supports SDG goals. Policy priorities include standards, subsidies, segregation, capacity building, and PPP-driven infrastructure.

Keywords: ***Organic waste, Municipal waste management, Biogas, Circular econoy.***

Introduction

Municipal solid waste management (MSWM) remains a critical challenge for Nepal's urban municipalities, where over 60% of waste comprises organic materials with high moisture content. According to Pathak (2024), the 293 municipalities in Nepal collectively generate over 5,000 tons of municipal solid waste (MSW) per day, with an average rate of 0.3 kg per capita per day. The total waste generation is projected to rise from 2.84 million tons in 2025 to 4.77 million tons by 2050. This rapid increase highlights the urgent need to adopt circular economy principles that convert organic waste from a disposal challenge into a valuable resource.

The current linear waste management system in Nepal, characterized by inadequate collection services and reliance on open dumping or engineered landfills, is both economically unsustainable and environmentally detrimental. Municipalities in Nepal spend approximately NPR 3,000 to 7,500 per ton for solid waste management, with minimal value recovery. This paper presents a comprehensive framework for organic waste valorization that aligns with Nepal's Sustainable Development Goals (SDGs) commitments and national solid waste management strategies, demonstrating how different scales of intervention can be optimized based on municipality characteristics, population density, and resource availability.

Household Composting

Household composting represents the most decentralized and accessible entry point for organic waste management in Nepalese municipalities. A case study from the Bagmati Corridor, where more than 6,000 compost bins were distributed across Kathmandu Metropolitan City (KMC), Gokarneshwor Municipality (GM), and Kageshwori-Manohara Municipality (KMM), demonstrates the viability and impact of this approach. Survey results from 400 households revealed that 99.5% practiced waste segregation, with 100% retention of distributed compost bins, indicating high user acceptance and sustained engagement.

The implementation study revealed that households practicing composting (33.8% of surveyed participants) produced 2-5 kg of compost per month. Extrapolating these findings to 4,000 households in the upper Bagmati Corridor, approximately 4 tons of biodegradable waste per day is being managed at source, yielding 1 ton per day of compost fertilizer. For Kathmandu Valley alone, if 5% of households adopt composting, approximately 36 tons per day of bio-degradable waste can be managed at source, saving NPR 270 k daily in MSWM costs.

Community-Scale and Municipal Co-Composting

For the organic waste fraction that cannot be managed at the household level (representing 75-85% of municipal organic waste), community-scale and municipal co-composting facilities offer an intermediate solution. Research conducted at Gulariya Municipality's co-composting plant demonstrated that combining MSW with dewatered faecal sludge (DFS) using sawdust as a bulking agent produces safe, high-quality compost meeting national standards.

Experimental trials revealed that the optimal mixing ratio of MSW:DFS:SD (0.42:0.34:0.24) achieved thermophilic temperatures of 65°C sustained for 12 days, resulting in complete pathogen elimination (zero helminth eggs and E. coli levels within permissible level). This configuration achieved 61.4% mass reduction over 60 days, with final compost containing required nitrogen, phosphorous and potassium (N, P, K) value, making it suitable for agriculture applications.

Co-composting addresses the dual waste management challenges by simultaneously treating organic waste and faecal sludge recovering valuable nutrients, reducing dependance on imported chemical fertilizers, and mitigating greenhouse gas emissions. For mid-sized municipalities (10k-50k population),

community-scale facilities processing 2-10 tons per day are appropriate, while larger municipalities (>100k population) require municipal-scale facilities handling 20-100 tons per day are appropriate. Based on city level practical experiences, these facilities require 2k-10k per m^2 of land depending on capacity, with capital investment ranging from NPR 10-50 million for community-scale operations.

Large-Scale Compressed Biogas (CBG) Plant

For large minicipalities and metropolitan areas generating substantial organic waste volumes (>70-100 tons per day), large-scale anaerobic digestion plants producing CBG represent the most economically viable and environmentally beneficial option. These facilities not only manage waste at scale but also produce renewable energy and high-quality organic fertilizer, creating multiple revenue streams.

Technical specifications for large-scale CBG plants indicate that land requirement for anaerobic digestion is 400-500 m^2/ton, including space for slurry drying (ADB, 2011). For example, a 100 ton per day organic waste facility requires approximately 4 hectares of land and produces 3,000-4,000 kg of compressed biogas (CBG) daily. Capital investment for processing 70-100 TPD source-sorted bio-waste ranges from NPR 600-800 million (Pathak, 2024).

Case studies from operational plants in Dharan, Dhangadhi, Ghorahi, and several other cities in Nepal show promising results. However, these plants continue to face significant challenges related to input material supply, marketing end products, and the absence of government policies that promote resource recovery. The 65 TPD plant in Suddhodhan Rural Municipality, Kapilvastu processes cow dung and press mud to produce 1,060 kg of Bio-CNG and 9.8 MT of fertilizer daily (AEPC, 2024). Similarly, the 4,000 m^3 plant in Pokhara operated by Gandaki Urja Pvt. Ltd. demonstrates commercial viability despite challenges related to feedstock quality and product marketing (Cheng et al., 2024). Economic analysis indicates that CBG plants can achieve positive returns when properly designed and operated. Revenue streams include CBG sales (substituting imported LPG at competitive prices), organic fertilizer sales, and carbon credits through verified greenhouse gas emission reductions.

Integrated Framework for Circular Economy Implementation

An integrated approach to organic waste valorization in Nepal should recognize the complementary roles of household, community, and large-scale interventions. The optimal waste management strategy varies by municipality characteristics.

Small and medium municipalities should prioritize household composting (15–25%) and manage remaining organic waste through decentralized community composting. Large cities should target 5–10% household composting and rely on centralized CBG plants, developed through cluster models to improve scale and support PPPs. This integrated framework advances circular economy goals by maximizing resource recovery, reducing disposal, producing renewable energy and fertilizers, lowering emissions, and improving public health.

Conclusion and Policy Recommendations

Organic waste valorization presents significant opportunities for Nepalese municipalities to transition from linear waste disposal systems to circular economy models that create economic, environmental, and social value. The multi-scale approach outlined demonstrates that appropriate technologies exist for municipalities of all sizes and characteristics, from household composting bins to large-scale CBG plants processing 100+ tons per day.

To realize this potential, the following policy interventions are suggested:

1. Establish clear national standards for compost and biogas products with certification mechanisms.
2. Provide targeted subsidies and financial incentives for household composting (NPR 500-1,000 per bin), community facilities (30-40% capital cost subsidy), and large scale CBG plants (low-interest loans and carbon finance).
3. Enforce mandatory source segregation of organic waste in all urban municipalities.
4. Build institutional capacity at municipal level for planning, implementation, and monitoring of organic waste management systems.
5. Promote public-private partnerships (PPP) for large-scale infrastructure development and operation.

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