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Waste-To-Energy Solutions with Vermicomposting: An Integrated Approach for Sustainable Urban Waste Management

Dr. Zeenat Surve
Assistant Professor, Department of Zoology Maharashtra College of Arts, Science & Commerce, Mumbai

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Correspondence Address:
Dr. Zeenat Surve
Assistant Professor, Department of Zoology Maharashtra College of Arts, Science & Commerce, Mumbai
Email: zeenatsurve1@gmail.com

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Abstract

Urban centers such as Mumbai generate over 7,000 tonnes of municipal solid waste daily, posing severe challenges for sustainable management. Conventional landfilling has resulted in environmental degradation, necessitating innovative approaches. This paper explores waste-to-energy (WTE) technologies and vermicomposting as complementary strategies. WTE technologies—including incineration, anaerobic digestion, gasification, and landfill gas recovery—enable energy recovery from waste streams. Vermicomposting, using earthworms such as Eisenia fetida and Perionyx excavatus, provides decentralized, eco-friendly composting that enhances soil fertility and reduces reliance on chemical fertilizers. Together, these approaches demonstrate how integrating advanced energy recovery with community-level composting can reduce reliance on landfills, support renewable energy goals, and promote circular economy principles.

Keywords: *Waste-to-Energy (WTE), Vermicomposting, Municipal Solid Waste, Sustainable Urban Waste Management, Circular Economy, Anaerobic Digestion, Biogas, Renewable Energy, Eisenia fetida, Soil Fertility.*

Introduction

Mumbai faces a **global-scale waste crisis**, generating over 7,000 metric tonnes of solid waste daily. Conventional landfilling has led to air, soil, and groundwater pollution. Waste-to-energy (WTE) technologies offer a sustainable solution by converting waste into electricity, biogas, and compost. However, WTE alone cannot address nutrient recycling. Vermicomposting complements WTE by transforming organic residues into nutrient-rich biofertilizer, creating a **zero-waste circular system** where energy and soil health are simultaneously enhanced.

Methodology

1. Study Design

This study adopts a **case-based analytical approach**, focusing on Mumbai's Deonar landfill WTE project and community-level vermicomposting initiatives in Ratnagiri district.

2. Data Collection

1. **Municipal Solid Waste Data**: Daily waste generation statistics from Brihanmumbai Municipal Corporation (BMC).
2. **WTE Plant Specifications**: Capacity, cost, and energy output of the Deonar WTE plant.
3. **Vermicomposting Practices**: Field observations and secondary data from farmers adopting vermicomposting.

3. Integrated Workflow

The proposed integrated system involves:

1. **Segregation & Pre-treatment** of municipal solid waste.
2. **Anaerobic Digestion** of wet waste to produce biogas.
3. **Digestate Stabilization** through aeration.
4. **Vermicomposting** of stabilized digestate using *Eisenia fetida.*

Results

1. **Waste-to-Energy Outcomes**

1. The Deonar WTE plant processes **600 tonnes/day**, generating **7–8 MW electricity**.
2. Expected reduction of nearly **2 crore tonnes** of accumulated waste.

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2 Vermicomposting Outcomes

1. Farmers in Ratnagiri reported **improved crop yields** and **enhanced soil fertility** after adopting vermicomposting.
2. Vermicompost reduced dependence on chemical fertilizers, lowering input costs.

3. Integrated Benefits

1. **Energy Recovery**: Biogas converted to electricity.
2. **Soil Fertility**: Vermicompost enriched with nitrogen, phosphorus, and potassium.
3. **Circular Economy**: Waste transformed into both energy and compost, minimizing landfill use.

Discussion

1. Synergy of WTE and Vermicomposting

The integration of WTE and vermicomposting addresses limitations of standalone systems. WTE captures immediate energy from high-calorie organic wastes, while vermicomposting stabilizes residual digestate into nutrient-rich compost.

2. Environmental Impact

1. Reduction in greenhouse gas emissions through methane capture.
2. Improved soil health via vermicompost application.
3. Pollution control through filters and scrubbers in WTE plants.

3. Challenges

1. **High Initial Investment**: ₹648 crore for Mumbai's WTE plant.
2. **Public Perception**: Concerns about incineration emissions.
3. **Segregation Efficiency**: Need for source-level waste segregation.

4. Future Prospects

1. Smart WTE plants with **AI and IoT monitoring**.
2. Integration with **urban smart grids**.
3. Expansion of **bio-CNG and biomethanation plants**.

Conclusion

Integrating WTE and vermicomposting offers a **holistic solution** for urban waste management. Benefits include energy security, waste reduction, improved soil fertility, and climate action. Adoption of these strategies is essential for sustainable development in rapidly urbanizing regions.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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