Quantifying Specific Emission Factors from Organic Waste Management

Mariam Khaled[1], Maged Abdallah[2], Rana Tarek[2], Nehad Ahmed[1], Sherien Elagroudy*[1]

[1]Egypt Solid Waste Management Center of Excellence, Faculty of Engineering, Ain Shams University, 1 Elsarayat St., Abassia, Cairo, 11517, Egypt.
[2]Public Works Department, Faculty of Engineering, Ain Shams University, 1 Elsarayat St., Abassia, Cairo, 11517, Egypt.
Keywords: Organic Fraction of Municipal Solid Waste, Greenhouse Gas Emissions, Solid Waste Disposal, Solid Waste Practices

*Presenting Author Email: s.elagroudy@eng.asu.edu.eg

Introduction

Municipal solid waste (MSW) management poses significant environmental challenges in Egypt, with waste generation averaging 28 million tons annually and only 60-69% of waste collected. The organic fraction of MSW (OFMSW), accounting for up to 60% of total waste, is frequently mismanaged, resulting in substantial greenhouse gas (GHG) emissions from open dumping and burning. This study evaluates four OFMSW management strategies—landfilling**,** composting**,** biodrying**,** and anaerobic digestion (AD)—in a residential-commercial area in Cairo, using IPCC 2006 guidelines and field data.

A study was conducted in a residential-commercial area in Cairo, Egypt to investigate the organic fraction of municipal solid waste streams, such as those from residential buildings, markets, restaurants, and public parks, with a focus on determining the generation amounts of the organic fraction, and to develop a framework for sustainable and smart OFMSW management considering the environmental, social, and economic perspectives.

Methodology

To assess the current situation of the Organic Fraction Municipal Solid Waste (OFMSW) in Egypt, a survey was conducted within a residential-commercial area located on the eastern outskirts of Cairo. This fully integrated area provides a high-quality living environment with a balanced blend of residential, commercial, and recreational areas, making it a self-sustaining community. Cross-sectional data were collected using structured questionnaires and interviews tailored to specific sectors, ensuring relevance to residential areas, the public park, and the mall. The Waste Wise Cities Tool (WaCT), developed by UN-Habitat, was systematically applied in this study. The survey was divided into three parts: (1) Demographic and household information, (2) Waste generation and composition, and (3) Waste collection frequency and segregation practices. Figure (1) shows Sankey diagram for the baseline scenario occurring in the residential area.

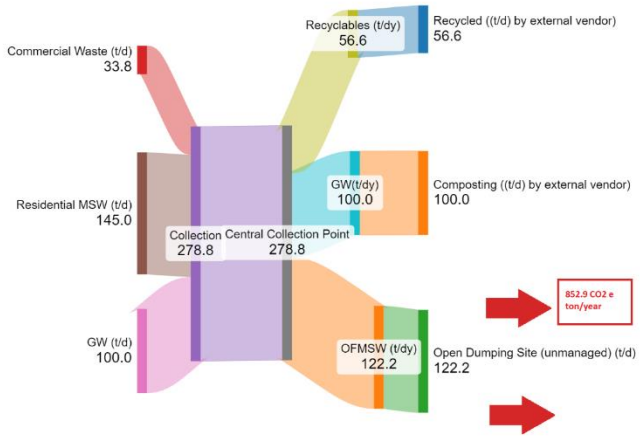

Figure 1 Sankey Diagram for the baseline scenario occurring in the residential area

Results and Discussion:

Once daily collection is completed from residential, commercial, and public sources, the MSW + GW are transferred to a central collection point CCP, that is located at the border of the residential area. At the CCP, manual sorting takes place whereby metals, plastics, glass, cardboard and paper are extracted under the term recyclables. The collective recyclables are then sold to a third-party vendor for further recycling and treatment. On the other hand, the green waste generated is sent to another third-party vendor for composting. Finally, the OFMSW from both the residential and the commercial areas, contributing to around 122.2 tons/day will be transported by a contractor to be openly dumped. This open dumping area is particularly a high-traffic zone, exposing thousands of Cairo citizens driving by or walking by for transportation to pathogens and harboring a collection of rodents and insects leading to further disease-spreading. The current waste disposal practices are depicted by **Error! Reference source not found.**. As shown, this results in the daily emissions of 852.9 CO_2 e tons/day.

Using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (CH_4 Emissions from Solid Waste Disposal), the GHG Emissions for the current solid waste practices, specifically disposal, has been calculated using the equation below:

$$\text{Methane emissions (ton/year)} = (MSW_T \bullet MSW_F \bullet MCF \bullet DOC \bullet DOC_F \bullet F \bullet 16/12 - R) \bullet (1\text{-}OX)$$

As indicated in Table , methane emissions from OFMSW are estimated at 19.3 tons/day from residential sources and 5.8 tons/day from commercial sources. These figures are particularly concerning given the potency of methane, which has a 100-year global warming potential (GWP) of 34 according to the AR6 report. Consequently, the emissions from OFMSW are projected to contribute approximately 852.9 tons of CO_2 e tons/day. For the year 2024, the anticipated total emissions are expected to reach 311,320.1 CO_2 e tons. By 2034, residential municipal solid waste is forecasted to rise from 145 to 252 tons/day, while commercial waste is expected to grow from 33.8 to 73 tons/day. The anticipated methane emissions for 2034 are projected to be 16,935.6 tons/ year, translating to 575,811.2 CO_2 e tons/year, representing an increase of 45% over the next decade.

Table 1 Estimation of methane emissions caused by open dumping of OFMSW

	Residential Area Waste (ton/day)	Commercial Area Waste (ton/day)	Reference
MSWT	145	33.8	Survey
MSWF	64.70%	83.90%	Survey
MCF	0.8	0.8	IPCC default values for unmanaged deep dumping sites
DOC	0.5	0.5	
DOCF	0.77	0.77	IPCC default values.
F	0.5	0.5	IPCC default values.
R	0	0	IPCC default values.
OX	0	0	IPCC default values.
Total (CH4 ton/day)	19.3	5.8	-
Total (CO_2 e ton/day)	655	198	-
Total of both streams (CO_2 e ton/year)	311,320.1		-

The landfill scenario, characterized by unmanaged methane emissions, results in 311,320.1 tons CO_2e/year. Composting, while improving soil nutrients, produces significant emissions of 25,648,805.2 tons CO_2e/year due to methane and nitrous oxide release. Biodrying, used to enhance waste calorific value for energy recovery, generates the highest emissions at 33,292,143.7 tons CO_2e/year, largely driven by energy-intensive operations. In contrast, anaerobic digestion emits just 3,069,765.6 tons CO_2e/year, leveraging biogas recovery to offset emissions and provide renewable energy.

The findings identify anaerobic digestion as the most sustainable solution for Cairo's OFMSW, significantly reducing emissions while aligning with Egypt's Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs). This study underscores the urgent need to adopt advanced technologies like AD to mitigate GHG emissions, promote energy recovery, and support a circular economy. Effective policy interventions and sustainable waste practices are critical for addressing Egypt's growing urban waste challenges.

References:

Déportes, I., Benoit-Guyod, J., & Zmirou, D. (1995). Hazard to man and the environment posed by the use of urban waste compost: a review. The Science of the Total Environment, 172(2–3), 197–222. https://doi.org/10.1016/0048-9697(95)04808-1

Echavarri-Bravo, V., Thygesen, H. H., & Aspray, T. J. (2016). Variability in physical contamination assessment of source segregated biodegradable municipal waste derived composts. Waste Management, 59, 30–36. https://doi.org/10.1016/j.wasman.2016.10.049

Egypt Ministry of Environment (2023) Egypt's Updated First Nationally Determined Contribution 2030

Elfeki, M., & Tkadlec, E. (2015). Treatment of municipal organic solid waste in Egypt. Journal of Materials and Environmental Science, 6(3), 756–764.

Hemidat, S., Achouri, O., Fels, L. El, Elagroudy, S., Hafidi, M., Chaouki, B., Ahmed, M., Hodgkinson, I., & Guo, J. (2022). Solid Waste Management in the Context of a Circular Economy in the MENA Region. Sustainability (Switzerland), 14(1). https://doi.org/10.3390/su14010480

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F. Van. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*.

Montané, D., Abelló, S., Farriol, X., & Berrueco, C. (2013). Volatilization characteristics of solid recovered fuels (SRFs). Fuel Processing Technology, 113, 90–96. https://doi.org/10.1016/j.fuproc.2013.03.026

Moussa, R. R. (2022). The potential of using anaerobic digesters in developing countries. Cleaner Engineering and Technology, 9, 100517. https://doi.org/10.1016/j.clet.2022.100517

Nassar H, Biltagy M and Safwat AM (2023) The role of waste-to-energy in waste management in Egypt: a techno-economic analysis. Review of Economics and Political Science. DOI: 10.1108/REPS-09-2022-0062.

Policastro, G., & Cesaro, A. (2022). Composting of organic solid waste of municipal origin: The role of research in enhancing its sustainability. International Journal of Environmental Research and Public Health, 20(1), 312. https://doi.org/10.3390/ijerph20010312

Van Fan Y, Jarimir Klemes J, Tin Lee C, Perry S (2018) Anaerobic digestion of municipal solid waste: energy and carbon emis sion footprint. J Environ Manage 223:888–897. https ://doi. org/10.1016/j.jenvman.2018.07.005

Bhatsada, A., Patumsawad, S., Towprayoon, S., Chiemchaisri, C., Phongphiphat, A., & Wangyao, K. (2023). Modification of the Aeration-Supplied configuration in the biodrying process for Refuse-Derived Fuel (RDF) production. Energies, 16(7), 3235. https://doi.org/10.3390/en16073235

Zaman, B., Hardyanti, N., Samadikun, B. P., Restifani, M. S., & Purwono, P. (2021). Conversion of municipal solid waste to refuse-derived fuel using biodrying. IOP Conference Series Earth and Environmental Science, 623(1), 012003. https://doi.org/10.1088/1755-1315/623/1/012003

Arab Development Portal (2015) *The Sustainable Development Strategy (SDS): Egypt Vision 2030*.

UNEP. (2024). Global Waste Management Outlook 2024: Beyond an age of waste - Turning rubbish into resources.

Manageruser. (2023, February 17). IPCC Sixth Assessment Report Global Warming Potentials - ERCE. ERCE. https://erce.energy/erceipccsixthassessment/