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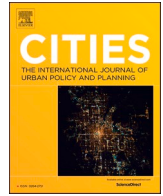
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Reimagining urban waste management: Addressing social, climate, and resource challenges in modern cities

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ABSTRACT

Governments worldwide are seeking better solutions for solid waste management. Thermal treatment projects are presented as quick fixes for rising waste challenges, without addressing the limitations of incineration. Currently, there is a rise in proposals for thermal treatment technologies in developing countries. Scrutiny of the risks and impacts of these alternatives is necessary due to social, climate, and resource considerations. Energy from waste incineration is considered fossil energy since about half of the CO₂ emissions come from fossil polymers in the waste. From a sustainability perspective, landfilling is a short-term option for materials currently unsuitable for recycling. Landfills act as bioreactors, producing valuable biogas, and serve as “resource banks,” storing unrecyclable resources until better recycling techniques are developed. In developing countries manual labor is abundant and material sorting and landfilling are more valuable and have a lower climate and resource footprint. This paper offers a novel, integrated perspective of waste management in view of poverty reduction, climate change and resource conservation.

1. Introduction

The global rise in solid waste presents urgent social, economic, and environmental challenges, especially amid the climate crisis and dwindling resources. Innovative technological advances based on the notion of smart cities, that work in the global North, might not be appropriate for global South contexts (Boubaris et al., 2022; Konstantinidis et al., 2023; Zoumpoulis et al., 2024). This article evaluates municipal waste management methods—landfilling and incineration—in developing nations, considering their social, climate, and resource impacts. Recycling has drawbacks like energy and water consumption, emissions, space and infrastructure requirements as well as transportation related impacts, however, it aligns better with ‘socially restorative’ circular economy principles (Barford & Ahmad, 2021; Gutberlet, 2023; Nizzetto and Sinha, 2020). While these impacts from recycling need to be addressed, this paper, will scrutinize primarily landfilling and incineration, from a global South context.

Governments worldwide grapple with waste management deficiencies and littering (Niyobuhungiro & Schenck, 2022), open burning (Cogut, 2016; Velis & Cook, 2021) and the problems generated by lack of recyclability of discarded materials (Akmal et al., 2023). Developing

countries further must deal with high poverty rates, social exclusion and low levels of formal education and environmental awareness (Abubakar et al., 2022; Dias, 2016; Navarrete-Hernández & Navarrete-Hernández, 2018). Nevertheless, in this part of the world, large numbers of autonomous and organized waste pickers are the main workforce collecting recyclables, separating and selling them to the industry (Gutberlet et al., 2017).

In some global South cities, we see a come-back of incineration with waste-to-energy (WtoE). Yet, in Europe recent political decisions prioritize recycling over thermal treatment, leaving most EU countries with an incinerator over-capacity (Massarutto et al., 2019). According to the present trends, no new incinerators will, be built in Scandinavian countries as the view of waste in a ‘circular economy society’ strongly focuses on material recovery (Levidow, 2023). In Denmark, for instance, even relatively new waste incinerators are shut down due to new regulations favoring optimized source separation for material recycling (Lybæk, 2024). Swedish incinerators today must already import waste from all over Europe to fill their capacity (Mattson et al., 2024).

Since 2000, in response to the urban waste crisis, specifically in Latin America and Asia, waste incineration has resurfaced as an alternative, being specifically promoted as potential solution to the plastic waste

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challenges (Ahmed et al., 2024). This narrative has become popular, even though most plastics are of fossil origin and burning contributes to global warming. The advocacy for WtoE is led by global institutions such as the Global Waste-to-Energy Research and Technology Council, whose mandate is to globally expand this technology (Global WtERT Council, n.d.). Established in the USA in 2003, this Council has developed partnerships endorsing this technology in several countries, mostly in Europe but also in Brazil, Chile, Colombia, India and the Philippines (ABREN, 2021).

Social dimensions in waste management include the role informal waste workers play in urban areas in developing countries where services are inadequate or missing. Their contribution is often not taken into consideration when deciding over waste management options. This article seeks to shed light on the social and environmental aspects to guide policymakers and practitioners, emphasizing the need to consider employment, climate impacts, pollution, and resource conservation in waste governance.

2. Methods

This research is based on the review and analysis of academic publications, documents, reports, statistics and web sources. The databases chosen for the academic literature review were Scopus, Google Scholar and Web of Science due to their global and multidisciplinary scope. The search was based on combining keywords that emerge from our abstract, specifically linked to landfilling and waste incineration/waste-to-energy and global South. We further prioritized articles after 2000 until 2024. We also searched the web for grey literature to access industry and government websites and review website contents and uploaded reports from these sources.

In addition, we drew on empirical insights and findings from qualitative research conducted in Brazil and Argentina by one of the authors, the principal investigator in the Mapping Waste Governance project (MWG, n.d.). Through this research one of the authors was able to interact with key stakeholders (including waste pickers and their organizations, government agents and non-governmental agents) over the past 4 years recording their opinions on landfilling and incineration. The second author, with access to documents in Swedish, supplemented our data with reports and evidence from Swedish industry and government sources.

Key information extracted from these texts (academic publications, grey literature, interview transcripts from the MWG project) were theme coded and systematized to build the main narrative on the impacts and benefits of two current waste management practices (landfilling and incineration) through the lens of potential social, climate, and resource impacts, centering on case studies from Brazil, Argentina, and Scandinavia.

3. Research results

Argentina and Brazil are highly urbanized countries, with most of their populations living in metropolitan areas. Over the past decade, waste generation in these countries has increased significantly, pushing existing landfills to their capacity limits. Biological transformation of waste, such as aerobic composting plants and small-scale projects, are scattered across both nations and material recycling is primarily done by informal waste pickers. Despite these efforts, large urban centers continue to struggle with the substantial volumes of waste generated daily.

There has been a notable surge in public and media discourse surrounding waste incineration, in both countries. Incineration, along with other high-temperature waste treatment systems, relies on combustion at elevated temperatures to reduce organic, combustible matter (such as paper, cardboard, and plastics) into inorganic and non-combustible residues. However, it also produces various byproducts, including gaseous emissions like fossil carbon dioxide, carbon monoxide, nitrogen

and sulfur dioxides, heavy metals (cadmium, chromium, lead, mercury), halogenic acids (hydrochloric acid), chlorinated aromatic hydrocarbons (dioxins, furans, chlorinated benzene derivatives), as well as particulate matter and solid waste in the form of ashes and slags (Titto and de Titto & Savino, 2019).

In Sweden almost 50 % of the carbon dioxide in the stack gasses is of fossil origin due to burning of plastics and other synthetic material and the authors calculate that about 10 % of the fossil CO₂ emissions in Sweden can be derived to waste incineration. In a major, industrialized city like Malmö with a population of almost half a million, the WtoE plant make up for about 20 % of the total fossil CO₂ emissions (SYSVA, 2024). The potential negative impacts on recycling rates and livelihoods are often overlooked.

While the case of Sweden highlights a retraction from waste incineration, Brazil's National Association of Energy Recovery (ABREN¹), is lobbying for waste incineration, advocating for policies and regulations conducive to its implementation. The authors have accompanied twelve large-scale incineration projects underway, with proposals to generate electrical power (ABREN, 2021). The most significant units are planned in the state of São Paulo, the Southeast of Brazil. One project is slated for the municipality of Mauá, designed to serve nine neighboring municipalities totaling 2.3 million inhabitants, incinerating 3000 tons of waste daily and potentially generating 77 MW (Dadario et al., 2023). This project has been approved by the state environmental authority. Another incinerator installation is planned for the metropolitan region of Campinas in Nova Odessa, and a third is projected for the coastal region Baixada Santista, centered around the city of Santos, to receive 2000 tons of waste per day with a generation of 50 MW (Valoriza, 2020).

This development has not gone uncontested. The authors have accompanied the mobilization of local communities, waste picker organizations, environmentalists, and government agents to inform policymakers and the public about the potential implications of waste incineration, also described by Demaria and Schindler (2016).

The project in Mauá was recently suspended by the judiciary due to irregularities in the public hearing process. Policymakers across the country have proposed legislative changes to restrict thermal waste treatment. For example, Legal Project No. 4980/20, introduced by Congressperson Célio Studart Barbosa (Federal deputy from 2019 to 2023 for the Green Party, Ceará), sought to prohibit household waste incineration (Câmara dos Deputados, 2020). In March 2021, a new law was proposed for the Federal District of Brasília, the capital of Brazil, by Congress members Leandro Grass and Arlete Sampaio, aiming to replace incineration with “technology that does not endanger human health and the environment” and ensuring waste pickers' access to recyclable materials in the waste stream (Correio Brasiliense, 2020).

Contrary to these proposals, a change to federal waste management legislation was proposed by the conservative party (MDB-Espirito Santo) in January 2022, suggesting waste incineration as an alternative to sanitary landfills (Agência Senado, 2022). Supporters argue that these facilities reduce the waste volume by 90 %, occupy less space and save costs, without mentioning the associated environmental impacts.

Argentina is experiencing similar trends favoring WtoE expansion, garnering attention as promising business opportunities for international agencies and corporations within the waste management sector (Holland Circular Hotspot, 2021). Seven new incineration plants have recently been proposed for the metropolitan region of Buenos Aires. Once again, the WtoE industrial lobby, alongside segments of the government, is advocating for modifications to the existing Zero Waste legislation, Law 1854, established in 2005, creating opportunities for the incineration industry. The amended law permits incineration as a treatment option.

Landfilling poses its own set of challenges, lack of space being the main one. Well-documented adverse effects include methane

¹ ABREN Associação Brasileira de Recuperação Energética de Resíduos

production, a potent greenhouse gas emanating from the organic fraction of waste, and leachate, which can turn toxic and contaminate nearby water systems, jeopardizing ecological habitats (Themelis & Ulloa, 2007). Landfills also pose the risk of surface fires or subterranean combustion, leading to air pollution and greenhouse gas emissions.

However, most of these environmental problems can be solved with better technologies, e.g., bottom plastic liner systems, leachate collection and landfill gas extraction. In Sweden, as well as in the US, up to 95 % of the produced landfill gas can be collected in highly managed landfill test cells. Here, a normal average gas collection rate for landfills is around 75–80 % of the produced biogas. Calculations have shown that a collection rate of more than 65 % of the landfill gas results in a positive effect on climate change, due to the landfill being a long-term sink for organic carbon (Bramryd & Johansson, 2011).

Zero Waste Europe (2020) has recently released a Policy Briefing emphasizing that WtoE should not be classified as recycling; instead, it represents a diversion of resources away from the Circular Economy. The European Union has implemented stricter regulations on waste incinerators with better pre-separation of recyclable material and penalty fees for incinerators based on the level of plastics content in the waste they receive. It is expected that these regulations will decrease the numbers of WtoE plants in coming years (SYSAV, 2024).

4. Discussion

The following section discusses waste management from social, climate, and resource perspectives, exploring landfilling and incineration and their impacts on recycling, evidencing long-term sustainable waste management solution concepts.

4.1. Waste a social issue

In many developing countries, a significant portion of waste management is shouldered by waste pickers who collect and divert materials from the waste stream, contributing to reuse and recycling efforts. These individuals recover aluminum, multiple plastics, cardboard, paper, metals, glass and other materials, to sustain their livelihoods. Remarkably, they serve as the backbone of the recycling industry in their respective cities and regions.

In Brazil over 400,000 waste pickers, of which 39 % are organized in 1600 groups nationwide (MNCR, n.d.; Dagnino & Johansen, 2017), and in Argentina, roughly 200,000 waste pickers (FACCyR, n.d.), and 25,000 alone in the capital, organized in over 110 national cooperatives operate the recycling system. In some municipalities waste pickers are part of the official waste management program, and the national waste pickers' movement has successfully influenced public policies to support their work. In Brazil, recycling plays a pivotal role in job creation supporting the circular economy, with 89 % of what reaches the recycling industry being recovered by waste pickers (MNCR, n.d.). Increased recognition and participation in initiatives such as the 'Recycling Exchange' program in Minas Gerais state, compensates them for their contributions to Urban Environmental Services (Dias et al., 2021).

Similarly, in Argentina, waste picker organizations continue to gain momentum and in 2012, they established the National Federation of Waste Pickers (O'Hare & Sorroche, 2019). This network collaborates with a broader trade union of informal workers, the Workers Union of the Popular Economy (UTEP). These second-level organizations in Argentina and Brazil spearhead efforts to assert their rights as social and environmental service providers, emphasizing their roles in promoting the circular economy (Rutowski & Rutowski, 2015).

Additional social gains from inclusive waste management, include (a) low barrier job creation; (b) inclusion of vulnerable populations; (c) improved environmental health, as result of waste pickers educating households on source separation and recycling. These services are not yet acknowledged nor remunerated.

Incineration poses a threat to these social gains, jeopardizing the

livelihoods dependent on recycling and hindering the potential growth of inclusive waste management initiatives.

4.2. Waste a climate issue

Waste is not carbon neutral. Depending on its content, it contributes to greenhouse gas emissions. The climate impact of waste management varies depending also on the technology employed.

Energy from waste is fossil-based. Normally, over 50 % of the CO₂ in the stack gas from a waste incinerator has a fossil origin due to the presence of plastics in our waste. This characterization places major incinerators in Sweden, such as those in Malmö, Linköping, and Stockholm, on the list of the "15 major single emission sources of fossil CO₂ in Sweden" (Lundberg, 2020). Waste incineration alone is estimated to account for about 15 % of total fossil emissions in Sweden, equivalent to emissions from all vehicular traffic and the entire building industry, including energy-intensive cement and concrete production in Sweden.

In response to growing environmental concerns, the EU is increasingly advocating for CO₂ capture techniques from waste incinerators and from posterior storage sites, e.g., in porous bedrocks deep beneath the sea. Sweden mandates the construction of Carbon Capture and Storage (CCS) plants for incinerators in cities like Malmö, Helsingborg, and Stockholm, a trend echoed in Denmark, Germany, the Netherlands, and other European nations. However, while CCS offers a potential solution, it comes with its own challenges, including the emergence of air and water pollution, as highlighted in a Norwegian report (Hafslund Oslo Celsio, 2023). Moreover, CCS is costly and energy-intensive, with estimates suggesting a significant financial burden, making it less feasible for developing countries. In some cases, the CCS technique is expanded to possibilities to use the collected CO₂ as a resource (CCU – carbon capture and utilization) instead of burying it in abandoned oil extraction fields or in porous bedrock. So far, this new technique has mainly been discussed for CO₂ collected from other stack gas sources than waste incinerators. Even after an extensive stack gas purification system, flue gasses from waste incineration still have significantly higher loads of toxic organic or inorganic components that makes utilization of the collected CO₂ problematic.

A trend toward stricter regulations and ecotaxes such as observed in Sweden, where levies apply on emitted nitrogen oxides (NO_x) and fossil CO₂ emissions, may become global, impacting the economic viability of WtoE. Efforts to mitigate emissions from incinerators might also produce unintended consequences which need to be addressed early on.

On the other hand, well managed landfills can serve as long-term carbon accumulators, aiding in offsetting global warming by sequestering organic carbon (Bramryd & Johansson, 2011). When more than 60 % of the biogas generated is collected, landfills effectively capture organic carbon, akin to the role of natural peatlands and other carbon-storing ecosystems (Bramryd & Johansson, 2012). This not only helps governments meet their greenhouse gas reduction targets but also provides opportunities for energy generation and industrial applications using collected landfill gas. Methane captured at landfills plays a crucial role in reducing greenhouse gas emissions.

4.3. Waste a resource issue

Recycling programs help recover valuable resources by diverting materials from the waste stream, enabling the recycling industry to make new products. This process reduces the demand for virgin materials, thereby minimizing the environmental impacts and pollution associated with resource extraction (Lepawsky, 2022).

Burning materials for energy generation not only destroys valuable resources but also ranks low in the waste hierarchy, failing to promote awareness and action toward waste reduction, reuse, and recycling. In response to stricter legislation in Europe, incinerator operators are increasingly under pressure to reduce the plastic content of their waste inputs. Some have implemented pre-sorting facilities to separate plastics

from mixed waste before incineration, a significant departure from previous practices where plastics were routinely incinerated due to their high calorific value. Source-separated organic and food waste can also be repurposed through composting and anaerobic digestion, producing biogas and solid residues suitable for soil improvement in agriculture (Mourad, 2016).

For materials not yet recyclable, landfills may still be the best place to rest. Accumulating plastics, nylon, synthetic rubber, and other unrecycled fossil-based resources in landfills can be viewed as resource storage. Urban mining involves extracting valuable resources from ‘anthropogenic resource stocks’ (Habib, 2019) which might become the process helping conserve the environment, making use of disposed materials and diminishing our ecological footprint.

Like landfill biogas extraction (Weiland, 2009), nutrients can also be collected from landfill leachate. Heavy metals, under anoxic conditions, firmly bind up to the organic matter remaining in the landfill and appear in the leachate which can be separated at landfills (Brander et al., 2004). This form of resource recovery is not possible with incineration. Fly-ashes from waste incinerators are considered ‘toxic waste’ by the European Union and need to be disposed of in regulated ways.

5. Final considerations

The present research with focus primarily on Argentina, Brazil and Scandinavia allows us to draw some general conclusions, which can also be applied to other countries. Waste incineration contributes to CO₂ emissions, due to the presence of plastics and fossil-derived polymers in the waste stream. In developed countries, these facilities are increasingly seen as outdated methods, indicating a trend away from this practice. In developing countries, however, WtoE is often perceived as potential solution to the waste management crisis. A strong industrial lobby in support of WtoE is often the driving force behind these developments.

Mixed waste does not qualify as renewable energy source (EU, 2018) and is considered a resource leakage, away from the Circular Economy (EU Technical Expert Group on Sustainable Finance, 2020). Research shows that waste prevention and recycling measures must be considered priority options (EU Technical Expert Group on Sustainable Finance, 2020). This knowledge is not yet widespread in the context of developing countries, where we still see a proliferation of WtoE proposals. Imported from wealthier nations, promising societal progress, local governments are enticed by the industry’s discourse, portraying WtoE as solution to mounting waste management challenges. This technology is expensive and requires long-term commitments, potentially locking municipalities into wasteful ‘technology scenarios’, where waste reduction, reuse, material recycling, and composting become less accessible.

Managed landfills, when properly executed, provide a superior waste management solution by enabling material recycling before landfilling. They capture biogas for energy, store non-degradable materials -like plastics- for future use, sequester biogenic materials, and allow for nutrient extraction from leachate. These ideas are not yet sufficiently disseminated, to support policymaking.

The paper shows that decisions on waste management have profound social and environmental consequences, requiring a deeper understanding from governments, businesses, and communities. A novel integrated assessment of the social, climate, and resource implications of waste treatment technologies needs to be in place to achieve carbon neutrality. Finally, key lessons learned from our case studies can be applied worldwide. By prioritizing inclusive waste management, societies can uphold social gains, create employment opportunities, mitigate climate change and preserve valuable resources for future generations.

CRedit authorship contribution statement

Jutta Gutberlet: Writing – review & editing, Writing – original draft,

Project administration, Methodology, Investigation, Data curation, Conceptualization. **Torleif Bramryd:** Writing – review & editing, Resources, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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