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Opportunities and challenges associated with municipal solid waste disposal: A case study of Malawian cities

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Abstract
Malawi, as a developing country, faces serious environmental and health challenges associated with waste generation, transportation and disposal. Currently, available waste services rendered to the public are not sufficient to accommodate all residents in all cities due to rapid urban population growth. This paper highlights challenges that hinder effective municipal solid waste handling in Malawi. The literature survey has shown that existing dumping sites are in a bad state and do not meet the required standards, thereby posing danger to the diversity, ecological systems, environment and public health. Waste reduction through recycling of organic wastes into farmyard manure, plastic and metals exist on a small scale among some households and they are getting income. The challenges associated with municipal waste management are inadequate funding, lack of disposal infrastructure, weak enforcement of rules and regulations and the use of inappropriate vehicles for waste transportation. The activities such as conversion of waste to energy, civic educating residents, promoting recycling activities, expanding waste collection services to all residents and opening new engineered landfills and sufficient funding of municipalities would upscale waste management process.

Keywords: *Municipal Solid Waste; Malawian cities; recycling; waste conversion to energy*

1. Introduction

Malawi is a landlocked country located in the southern part of Africa sharing its borders with Mozambique, Zambia and Tanzania (KPMG, 2012). The country's estimated population in 2019 was 18.6 million. With the population growth rate of 2.7 percent, Malawi's population is expected to double by 2038 (Lino and Ismail, 2017). Like many other developing Africa countries, Malawi has undergone rapid population but little economic growth in recent years, a situation that has resulted into an increased solid and liquid waste generation (Ding et al., 2021; Vazquez et al., 2020). Solid Waste Management (SWM) is a major challenge especially for urban areas in most developing countries like Malawi (Raab et al., 2021). The high concentration of wastes in cities requires construction of proper waste disposing facilities. The modern urban lifestyles consume a lot of resources and produces a lot of wastes. Solid waste management services are supposed to be offered to all communities, as they are associated with public and health issues (Woroniuk & Schalkwyk, 1998). Improper solid waste management is characterised by low garbage collection rates, rubbish piling on roadsides and nearby rubbish containers and unlawful dumping or burning of wastes in public spaces (Noufal et al., 2020). In the absence of solid waste collection services, residents have resorted into malpractices of burning solid waste with the sole purpose of reducing its accumulated volumes (Wu et al., 2021). There is strong

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scientific evidence that has indicated that burning of plastics is linked to existence cancer (Kanellopoulos et al., 2021; Kret et al., 2018). Furthermore, uncollected waste could cause allergies, and are also proven to be the bleeding grounds for pathogens for infectious diseases (Sessa et al., 2010). The greatest challenge affecting developing and developed countries around the world is the protection of human health and the environment from the disastrous effects of solid waste disposal (Al-Khatib et al., 2014; Baghaee Moghaddam et al., 2014). Considering that environmental protection is a big issue facing both emerging and advanced countries, the overall goal of waste management efforts is to reduce the proliferation of hazardous materials into the atmosphere (Jerie, 2016).

Several published papers have indicated that massive pollution of water and soil is largely associated with MSW dumping sites. Studies conducted in Brazil have further revealed that most of the physicochemical parameters tested such as coliforms, biochemical oxygen demand, dissolved oxygen, and phosphorus for surface water; lead, coliforms, and iron for groundwater; copper, cadmium, lead, and zinc for surface water and soil samples collected in vicinity of dumpsites and non-sanitary landfills were above Brazilian permissible limits (Morita et al., 2021). The results showed that the dumping sites were causing negative impacts in surrounding soils and water resources as well as public health risks. A separate study carried out by Al-Khatib et al., (2014) in Palestine, on solid waste management facilities in Hebron District, indicated that residents were much concerned with the rate at which water and soil were being polluted by MSW facilities, treatment and operations practices. A similar study was conducted to assess physico-chemical parameters on groundwater samples from two different MSW dumping sites in NE Poland. The results revealed severe effects of MSW dumping sites on groundwater quality (Kapelewska et al., 2019). Similar research outcomes have detected high levels of heavy metals in soil samples collected from nearby dumping sites in Banglung-Napal, India (Nie et al., 2021; Regmi et al., 2022). Furthermore, soil samples collected from Ramar dumping site in Assam, India, had high levels of Cr resulting into high soil contamination (Gujre et al., 2021).

Malawi has one of the fastest growing urbanisation rates in the world at 4.19 percent per year. Like all fast-urbanizing countries, Malawi's cities have serious challenges of increased accumulation of generated waste which has been attributed to high urbanization, limited resources to manage generated wastes, weak enforcement of rules and regulations and ineffective implementation of public works, just to mention a few. Malawi, being an agro-based country has most of its predominant waste products generated from agricultural wastes (Halle & Burgess, 2006). To add on that, human activities such as manufacturing and consumption of commodities also heavily contribute to waste generation and massive pollution if not managed properly (Alidoust et al., 2021). The forms of garbage produced by such activities are numerous and diverse. Waste generation is the production of unwanted materials as by-product of economic processes.

Industrial processes such as construction activities and power plants produce a wide range of solid by-products and residues. Globally, Municipal Solid Waste (MSW) generation was estimated to be over 1.3 billion tonnes per year in 2012, and, it is expected to increase to 2.2 billion tonnes per year by 2025 (Hoornweg and Bhada-Tata, 2012; Saadeh and Al-khatib, 2019). Sub-Saharan Africa countries are reported to produce approximately 180 million tonnes of rubbish each year, accounting for about 5 percent of global waste production (Ayeleru et al., 2020).

Total MSW production for all cities in Malawi roughly stands at 1000 tonnes per day, resulting in significant pollution (Kasinja and Tilley, 2018). The current anual waste generation is at 553 tonnes per day for Lilongwe and 435 tonnes per day for Blantyre (UNDP, 2015). Waste generation is expected to increase to 642 tonnes per day by the year 2025 and 803 tonnes per day in 2031 for Lilongwe whereas annual waste generation for Lilongwe is expected to increase to 485 tonnes per day and 673 tonnes per day in 2025 and 2031 respectively. It is therefore recommended that suitable investments be made in solid waste management in order to meet the increased waste generation (Halle and Burgess, 2006).

In Malawi, city assemblies and district town councils are solely responsible for waste collection, which is overseen by the ministry of local government. However, in Blantyre and Lilongwe Cities, a few other private companies are involved in rubbish collection in residential areas under private arrangement (UNDP, 2015). For example, it is documented that 74.1 percent of the waste generated in Blantyre City is collected by the Blantyre City Council and 5.9 percent is collected by private owned companies. In Lilongwe, 68.7 percent of the waste is collected and transported to dumping sites by private operators whereas 7.2 percent is managed

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by the Lilongwe City Council (UNDP, 2015). This implies that large volumes of the generated wastes in Lilongwe is transported to the dumping sites by private owned companies unlike in Blantyre City where large quantities of the wastes are handled by the Blantyre City Council (Halle and Burgess, 2006). However, current waste collection services can only effectively handle about 30 percent of total waste generated. This therefore, results into rapid solid waste accumulation in cities and other locations (Barré, 2014). City councils, on the other hand, have enacted a variety of bylaws and ordinances to address the expanding waste management crisis. These restrictions are rarely enforced due to lack of resources such as finances and garbage disposal infrastructure, hence waste continues to accumulate (Kasinja and Tilley, 2018).

Classification of wastes as toxic and hazardous, recyclable or non-recyclable, kitchen and combustible waste is the best first step in waste management (Nie et al., 2018). Most of the wastes collected in both cities are organic. Thus, the wastes can be categorised into household, market, commercial and industrial (Barré, 2014). The wastes such as food residues, plastic bottles, plastic papers and metals such as aluminium and copper are common (Turpie et al., 2019). In both cities, the largest proportion of wastes disposed of at dumping sites is household wastes at 40.3 and 68.3 percent for Blantyre and Lilongwe respectively. This is followed by market wastes at 27.0 and 18.8 percent for Blantyre and Lilongwe correspondingly (Turpie et al., 2019). The quantity of commercial and industrial wastes disposed of at Blantyre dumping site is higher as compared to that of Lilongwe. Lilongwe showed that large household wastes are transported and deposited at its dumping sites, which could be attributed to life style patterns (UNDP, 2015).

To the best of our knowledge, there are no published research papers with scientific information describing the status and health implications of these dumping sites located in the two cities under study. The fact that it is well documented that the dumping sites which are poorly managed pose a serious threat to diversity and ecological ecosystems, environmental and public health due to the leaching of several hazardous chemical substances emanating from the dumping sites into water bodies in the vicinity, exposing animals and human health at severe risk of chemical infections does not suffice the claim. Therefore, this paper aims at providing an insight into the relevant stakeholders on the health and environmental implications that may emerge due to the continuous negligence of maintenance and monitoring the conditions of these two dumping sites.

Materials and Methods

Study area

Figure 1 shows four Malawian cities namely: Mzuzu in the north, Blantyre in the south, Zomba in the southeast and Lilongwe, the capital. However, this study has focused on two large cities namely: Blantyre and Lilongwe cities are situated in southern and central regions, respectively. Blantyre is the main commercial city and recent studies have indicated that it is amongst ten cities that have been greatly affected by air aerosol pollution in the world. MSW disposal is these two cities understudy **is** mostly dominated by dumping, with little recycling, incineration and composting. The practice of dumping MSW is not appropriate for the developing countries like Malawi as the dumping sites (DS) do not meet the required standards resulting into considerable environmental pollution and ecological deterioration. It has also been reported that residents who are not connected to waste collection services have resorted to open dumping of wastes and also burning of the waste aiming at reducing volumes of accumulated uncollected wastes (UNDP, 2015). This has a bearing on greenhouse effect and damage of the Ozone layer.

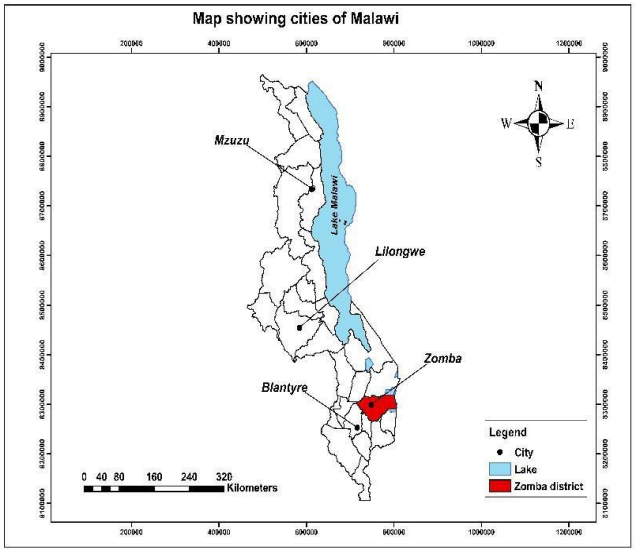

Figure 1. *Map of showing cities.*

Data sources

This study focused on literature review which was obtained by reading Malawi Government published reports and documents of relevant organizations

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responsible for MSW Management. Similarly, by searching published articles in scholarly databases such as ScienceDirect, PubMed, Google.com and Google scholar using search key terms "Landfills, Waste Management, Municipal Solid Waste and dumping sites."

Results and Discussions

Recycling

Recycling is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new usable products. Recycling can benefit communities and the environment (Obiri-Nyarko et al., 2021; Wang et al., 2020). In dumping sites waste pickers have formed informal groups with each group having specific collection type of waste (Turpie et al., 2019). The plastic papers are sold to recyclers whereas, metal steels which are mainly aluminium and copper are sold to metal traders. In remote areas some plastic wastes are used as a source of energy for cooking and brewing local beer (UNDP, 2015). However, the burning of plastics is associated with health related problems such as cancer (Heckel, 2021).

In some remote areas of Lilongwe specifically Mtandire (Fig. 2) some residents through non-governmental organizations have formed groups and they are trained on making compost manure from organic wastes which are sold and help in generation of income.

Figure 2. *Shows residents turning organic wastes into manure.*

MSW Disposal

Waste disposal does not only have a big bearing on the health of people and the environment but has also become a major setback in most developing countries (Chamdimba et al., 2020). In Malawi for example, MSW falls under the Department of Environment Affairs (DEA). DEA is responsible for implementing, monitoring, and enforcing environmental and waste management legislation and laws, as well as developing effective waste management strategies. However, MSW management is rarely prioritized in Malawi due to financial constraints (Halle and Burgess, 2006). This results into open uncontrolled dumping of MSW.

Management of MSW dumping sites

Waste Disposal Site is a place where ashes, garbage, refuse, domestic waste, industrial waste, municipal refuse and sewage is disposed of or dumped. Lilongwe and Blantyre have their own designated specific solid wastes disposal sites (DS) as shown in (Figure 3). The DS in Blantyre is situated at Mapanga (UNDP, 2015). The area is in close proximity to industrial developments, agriculture and villages. Whereas the DS in Lilongwe is situated at Area 38. Ironically, the site is surrounded by residential houses. The DSs in both cities have rivers and streams flowing within the vicinity. There are no effective management mechanisms in place in both of these DSs. The sites are not fenced and they are always open to the public at all times. Each DS has supervisor and general workers manning the sites. However, rampant illegal dumping of wastes has been observed in all the DS in these two cities (Turpie et al., 2019). This malpractice has severe impacts on surrounding areas and environment as dumped wastes are either blown away by wind or washed away water resulting into air and water pollution.

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Figure 3. *Showing dumping sites (a) and (b) thus Lilongwe and Blantyre respectively.*

Environmental and health issues associated with waste dumping sites

Literature survey has indicated that open dumping of solid wastes is the most popular practice by most cities around the world. Many investigators have condemned the unsustainable practice of using solid waste dumping sites as dumping grounds. This practice results into serious environmental issues and human health.

Several investigators have conducted assessments on various chemical substances within dumping sites and detected these chemicals in higher concentrations, posing a threat to the environment and human health. The most common detected chemical subatnces are reported in Table 1.

Leachate and odour

Leachate is one of the most common pollutants emerging from MSW landfills in the course of migrating into receiving waterways (Kumar et al., 2017). The results of a study conducted in Poland whose aim was to assess the chemical pollution and toxicity of water samples from the streams receiving leachate from controlled MSW land fill indicated high values of TOC and Conductivity down the stream as compared with samples collected from upper section of the stream. These results suggests a connection with the presence of the MSW landfill (Melnyk et al., 2014). Another study conducted in Algeria established that heavy metals, major ions and other physico-chemical parameters from an old landfill were attributed to degrading water quality and posing a health hazard to the people's lives (Foufou et al., 2017). This suggests that poor management of dumping sites has serious environmental and human health effects due to the prevalance of chemical substances emanating from these dumping sites.

Pathogens bleeding grounds

The wastes can sometimes act as vectors for disease-causing organisms, putting the public's health at risk (Njewa et al., 2022). It has been reported that two dumping sites were found to be inhabited by very big fly population and appeared suitable for bleeding grounds for a range of various fly species due to warmth emanating from decaying matter (Qasim et al., 2020). Furthermore, dumping of wastes on grounds emits methane gas due to the decomposition of organic matter (Magazzino et al., 2020). Other investigators have reported that greenhouse gases (GHG) such as methane and carbon dioxide are largely emitted from solid waste due to direct anaerobic digestion, aerobic composting, controlled burning in waste incinerators, mechanical biological treatment and landfill among others (Zurbrügg and Schertenleib, 1998). These gases are identified as major contributors to global warming and climate change. However, methane is a particularly much stronger GHG and is currently considered to have a global warming potential which is twenty five times more than that of carbon dioxide (Skillicorn et al., 2013).

Climate change

Climate change is a major international concern for modern society. Since the pre-industrial era, it has been indicated that the atmospheric concentration of carbon dioxide has increased by 35% and methane concentration has more than doubled. Sadly, solid waste disposal systems are among the contributors of climate change. They produce large volumes of GHG such as methane, sulphur dioxide, nitrogen dioxide and carbon dioxide. Studies conducted by Zaman and Lehmann (2011), reported that the global direct GHG

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emissions resulting from waste management activities are around 1.3Gt CO_2eq, which is also approximately 3 – 5 percent of total anthropogenic emissions. Currently, no single policy initiative or technology can effectively address the necessary GHG emission reductions to attain climatic stability but rather requires multiple mitigating options. The waste management sector must be included in this portfolio since it can reduce GHG emissions significantly (Khatib, 2016). Nevertheless, there is now convincing evidence that the waste management sector can radically change this image when connected avoided emissions are taken into consideration. As a result, effective disposal plays a critical role in reducing the impact of climate change.

Table 1. *Shows the most polluting substances present in Municipal Solid Waste*tegory Subgroup Examples

Category	Subgroup	Examples	Human and environmental effects	Reference
Inorganic pollutans	Heavy metals	Chromium, Copper, Lead Cadmium, Zinc, Iron	Cancer, birth defects nervous system disorder Kidney dysfunctional	Iravanian & Ravari, 2020
Organic pollutans	Pesticides	DDT Hexachlorocyclohexanes	Shakiness and seizures Carcinogen	Salam & Nilza, 2021
	Halogenated compounds	PCBS, Dioxins	Adverse effects on the nervous, Immune and endocrine system, Impair reproductive function, Cancer	Lud et al., 2022
	Volatile Aromatics	Benzene, Toluene, Xylene , Ethylbenzene	Attacks immune system, Nerve damage, kidney and liver Damage, loss of muscle coordination	Jiménez et al., 2010
	Plasticizers	Diethyl phthalate (DEP), EDTA	Endocrine disruption toxic, Mutagenic	Shikuku et al., 2022
	Phenols	Chlorophenol, Cresols, Ethyl phenol, Pentachlorophenol, 2,4-Dichlorophenol 3,4-Dichlorophenol	Liver and kidney damage Skin burns, Endocrine disruption	Schwitzguébel et al., 2002
	Anilines	2-Chloroaniline, 4,2-Toluidines, N-Methyl aniline, 2,4 dichloroaniline, 3,4-dichloroanaline	Methemoglobinemia, Severe coughing Difficult breathing	Jiménez et al., 2010
	Alkyl phosphates	Tris (2-butoxyethyl) phosphate, Tris (1,3-dichloro-2 propyl) phosphate Tri ethyl phosphate, Tris (2-chloropropyl) Phosphate	Fatigue, nausea, abdominal cramps, Diziness	Iravanian & Ravari, 2020
	Phthalates	Dibutyl phthalate, Diethyl phthalate Dimethyl phthalate	Damage the liver, kidneys, lungs Reproctive system	Jiménez et al., 2010
	Phenoxy acids	MCPP, 2,4-DP, silvex	Irritation to the skin, eyes, Respiratory, gastrointestinal, Mucous membranes	Jiménez et al., 2010
	PAHs	Fluorene, Naphthalene	Highly toxic, mutagenic, Carcinogenic, teratogenic, Immunotoxicogenic	Iravanian & Ravari, 2020
	Aromatic sulphonates	Naphthalene disulphonates, Naphthalene sulphonates, Aminonaphthalene disulphonates	Mutagenic Carcinogenic	Lange et al., 2000

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Challenges to effective MSW Management

The situation, of MSW management in Malawi, is currently in a bad state since the best and most appropriate waste collection and disposal procedures are not being implemented. Allocation of inadequate budgets to municipalities greatly affects operation of waste collection, transportation, treatment and disposal. Lack of engineered sanitary landfills which are well fenced and managed to reduce illegal dumping of wastes by residents has aggravated the condition. Implementation and enforcement of regulations and by-laws by city councils such as ensuring that private operators use appropriate covered vehicles for collection and transporting of wastes to dumping sites has been met. The residents in both cities have limited knowledge on environmental issues and lack creative ideas of transforming wastes into some useful substances such as biogas. Municipalities do not provide civic education to public on issues related to waste management, thus, another great challenge affecting MSW management sector in Malawi.

Recommendations to improve MSW in Malawi

Although MSW management is a big challenge in Malawi and globally, initiatives can be taken to improve the situation. One of the basic things to consider is political will. Governments should be in the fore front and should not only show interest but should also fund activities which are concerned with MSW handling. Some of the most important areas to address are as follows:

Civic educating residents.

The municipalities should civic educate residents, institutions and companies to be responsible for the garbage they generate. Ramos et al., (2012) argues that involving community in MSW management promotes the development of sense of responsible citizenship and ownership. This implies that residents and institutions should employ reliable waste management operators to handle their waste and dispose of it at an approved facility. Through civic education, the government can encourage residents to make compost manure from solid wastes and use them as organic manure to replenish degraded soils. Industries should be encouraged to form cooperatives that can press the government for laws and other forms of aid that will help them develop a well-managed and successful waste management service. Governments should further engage registered private operators with appropriate equipment and make sure that they comply with existing laws and regulations.

Conversion of Waste to energy

Most developed countries in Europe have adopted the principle of hierarchy which follows minimisation, re-use, recycle, recovery and disposal of solid wastes. These countries have embarked on huge energy recovery projects specifically non-recyclable waste materials into usable heat, electricity or fuel through a series of processes, including combustion, gasification, pyrolysis, anaerobic digestion and landfill gas recovery (Sipra et al., 2018).

Generation of Electricity

Gas is used as an alternative to other sources of energy. Electricity in Malawi is solely generated from hydro schemes which are situated on a single river. Of late, reports have indicated that water levels have gone down in the river due to climate change resulting into reduction in generation of electricity up to 67 percent (Chamdimba et al., 2020). The impact of climate change has affected Malawi recently especially as residents in the lower Shire experienced severe floods which claimed lives of people and affected the infrastructure at Nkula Hydro Electric Power Station leading to frequent and extended power outages. Other investigators have recommended conversion of MSW into electricity or feedstock to produce chemicals. This strategy is viable with novel and evolving technologies based on pyrolysis and gasification. This approach is preferred due to less emissions it sends into the atmosphere as opposed to conventional combustions(Lee, 2022; Ragazzi and Rada, 2012). Therefore, adopting conversion of waste to energy policy would help alleviate the problem of GHG emissions which come from degradation of organic matter.

Solid energy fuel

MSW from landfills such as plastics, wood and solid trash could be turned into useful materials especially in densely populated areas which generate large quantities of wastes. The promising technology would involve burning the high energy content residues in limited oxygen supply such as standard coal power plants (Gug et al., 2015). The generated rich carbon substance could be compressed and produce briquettes as an alternative source of energy. This could help reduce energy fuel issues if adopted which has greatly affected Malawi as most households are much dependent on charcoal for lighting and cooking. The fact that government has

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put restrictions on charcoal usage to save trees which are being heavily harvested without replacement is one laudable step to controlling global warming as deforestation contributes to high concentrations of greenhouse gases in the atmosphere promoting global warming (MS. Report, 2017).

Promoting recycling activities

This strategy of waste management is highly recommended and is considered as the best option to manage wastes which have already been generated and collected as it transforms the residues into desirable and useful secondary products (Quina et al., 2008). Recently, in Xiamen in China, people have formed a society termed as Nexus whose aim is to promote local industries in reusing MSW and standardisation of the products (Kurniawan et al., 2021). It has also been suggested that establishment of recycling network is important to accomplish the effective MSW management (Lv et al., 2020). Again, direct melting recycling is another available option which involves melting several wastes via a single route and their ashes are turned into slag and metal for recycling (Osada, 1997).

4. Conclusion

The MSW dumping sites in both cities are not appropriate as they are in bad state and do not meet the required standards posing a serious threat to ecological ecosystems, diversity and humans. The residents in communities staying in the vicinity of the dumping sites have embarked on income generating activities through recycling of wastes. The effective management of MSW is greatly compromised by less funding, use of open vehicles for collecting and transporting wastes, insufficient disposal infrastructure and weak enforcement of laws and regulations. The initiatives such as increasing recycling, civic education of residents, conversion of wastes into energy and increased funding to city councils are recommended to promote waste management operations.

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Conflict of interest

The authors declare that there are no conflicts of interest as the paper has not been written on behalf of or with funding from any organisation that deals with solid waste management.

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