LCA of De-Graft MSW management software implementation in Kenya – Final Report

De Graft Management (DGM) provides software solutions for property, asset and waste management. This report has been produced by the Sustainability Research Institute (SRI) of the University of East London (UEL) under its ARENA programme. The report provides an environmental life cycle assessment of alternative municipal solid waste (MSW) management solutions applicable to Nairobi, Kenya that could be enabled by the implementation of DGM waste management software.

Introduction

Environmental Life cycle assessment (LCA) has been extensively applied to evaluate environmental burdens associated with municipal solid waste (MSW) management. In addition to quantifying the environmental impacts and burdens associated with waste management options, LCA can also be used to explore opportunities for improvements (Cherubini et al, 2009) and to help expand the perspective beyond the waste management system. This makes it possible to take into consideration the significant environmental benefits that can be obtained through alternative waste management options (Wang et al, 2020). The methodology adopted is a process-based study of alternative waste management options, implemented in Simapro 9.3 (Simapro, 2022), using the characterisation method CML-100 and focusing on one environmental impact category, global warming potential (GWP).

Goal and scope

This study assesses how the implementation of new waste management software developed by DGM might affect the GWP of MSW management in Nairobi, Kenya (which is used as a proxy for four regions of Nairobi, Nakuru, Nyeri and Mombasa), by quantifying the GHG emissions from alternative MSW management scenarios using LCA. Emissions are quantified and compared between several 'business as usual' (BAU) scenarios reflecting current practice and a series of alternative scenarios that might be enabled or facilitated by the implementation of DGM software to improve waste management by stakeholders. The functional unit is defined as the treatment of one tonne of MSW. In accordance with LCA standards, emissions associated with processing MSW removed for recycling are excluded from this study as they fall within the boundary of an additional life cycle for the recycled material, rather than that of the material in the waste stream.

Life cycle inventory analysis

The data on MSW generated by households daily in Nairobi and current routes of waste disposal is taken from the UN Habitat survey (2019) and is shown in Tables 1 and 2 and Figure 1. The UN report assumes that MSW generated from non-household sources represents an additional 30% in mass, composed of materials in the same proportions as the MSW from households described in Table 1. The breakdown of MSW disposed of daily by type and destination, shown in Table 2, has implications for the inventory analysis. Firstly, it suggests that current documented recycling rates vary by material between zero In the case of wood; and 186% in the case of paper and card. Such a rate in excess of 100% indicates that amounts of MSW recovered daily for some materials can exceed the amounts generated daily for those materials, implying that the amount of paper and card recovered daily must include material taken from the stock of existing waste paper/card dumped previously.

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Table 1: Input parameters, based on survey of domestic MSW generated in Nairobi (UN, 2019).

Input parameter	Unit of measure-ment	Daily total (tonnes)	% of total waste stream	Dataset used to represent input parameter within Simapro LCA software
Putrescibles(kitchen/canteen)	Metric tonne	1258.9	55.0%	Brown rice (mixed) at processing/ CN mass
Putrescibles(garden/park)	As above	51.3	2.2%	As above
Paper and card	As above	198.3	8.7%	Printed paper (GLO) market for, cutoff, S
Plastic – dense	As above	176.1	7.7%	PET, granulate, bottle grade, (GLO) market for, cut off, S
Plastic – film *(assumed to be split equally between PE and PP)*	As above	48.1	2.1%	Polyethylene, low density, granulate, (GLO), market for, cut-off, S
		48.1	2.1%	Polypropylene, granulate, (GLO), market for, cut-off, S
Glass	As above	90.1	3.9%	Packaging glass, white, (GLO), market for, cut-off, S
Textiles /shoes	As above	92.4	4.0%	Fibre, cotton, organic (GLO), market for, cut-off, S
Wood	As above	51.1	2.2%	Wood chips from post-consumer wood measured as dry mass (GLO) market for, cut-off, S
Metals	As above	31.3	1.4%	Steel, unalloyed, (GLO), market for, cut-off, S
Waste electronic equipment	As above	37.4	1.6%	Cable, unspecified, (GLO), market for, cut-off, S
Hazardous household waste	As above	42.2	1.8%	N/A as no equivalent dataset available
Other (mixed)	As above	164.7	7.2%	N/A as no equivalent dataset available
Input parameter	**Unit used**	**Average distance travelled (km)**		**Dataset used to represent input parameter within Simapro software**
Transport	tonne km	13.5		Municipal waste collection service by 21 metric tonne lorry, (GLO), market for, cut-off, S

Table 2: Disposal of MSW by material type and destination for Nairobi (UN, 2019)

Daily MSW disposal by material	Amount collected (tonnes)	% of material collected	Am't un-collected (tonnes)	% of material uncollected	Removed for recycl'g (tonnes)	% Removed for recycling
Putrescibles (all types)	1267.2	74.4%	435.9	25.9	5	0.3
Paper and card	191.8		66.0	-	480	186.2
Plastic – dense	170.3	74.4%	58.6	25.9	30	13.1
Plastic – film	93.1	74.4%	32.0	25.9	45	36.0
Glass	87.2	74.4%	30.0	25.9	85	72.6
Textiles /shoes	89.4	74.4%	30.8	25.9	8	6.7
Wood	49.4	74.4%	17.0	25.9		-
Metals	30.3	74.4%	10.4	25.9	0.8	2.0
Waste electr. equipment	36.2	74.4%	12.4	25.9		-
Hazardous h'hold waste	40.8	74.4%	12.0	25.9		-
Other (mixed)	159.3	74.4%	54.8	25.9		-
Total	2,215		762		653.8	

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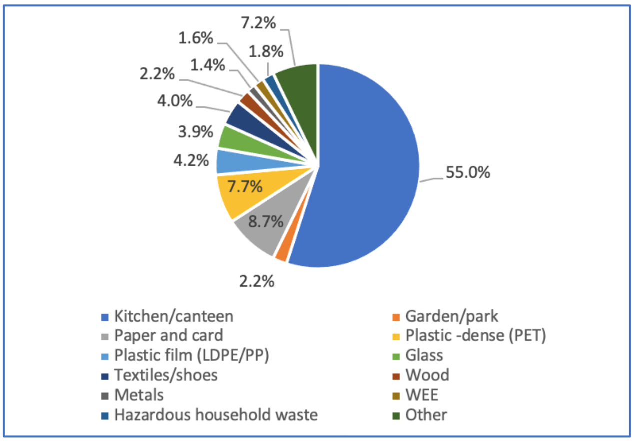

Figure 1: Breakdown of MSW generated daily by material, Nairobi (UN, 2019)

Not all of the materials making up the MSW stream generated in Nairobi have been included in the analysis, as indicated in Table 1, as datasets were not available to represent 'hazardous household waste' and 'other' materials, both of which were miscellaneous categories of multiple materials. However, the hazardous waste can safely be excluded under LCA 'cut-off' rules as it makes up less than 2% of the mass of the functional unit of 1 tonne of MSW, whilst the exclusion of the 'other' materials is unlikely to influence the analysis as this is a mixed category of mainly unspecified materials whose relative proportions are not provided by the UN report (2019).

Life cycle impact assessment

The scenarios used to conduct the impact assessment, shown in Table 3, model the effects of a range of alternative waste disposal options against several BAU options. The alternatives are all plausible policy options within the scope of improved waste management strategies in Kenya. It is assumed that any of these alternatives might be enabled or facilitated by the use of DGM software. S1a and S1b represent the current status quo and only differ in that uncollected waste is either dumped or burned in the open, whilst collected waste is either sent to unsanitary landfill sites such as Dandorah, or removed for recycling. S1c slightly modifies BAU by assuming that all MSW might be collected, however this only leads to more waste going to unsanitary landfill and an unchanged amount being removed for recycling. Scenarios 2 and 3 are both used to model the impact of varying proportions of organic waste being composted or sent to an anaerobic digestion facility, with no change to the disposal of other types of waste. Scenario 4 models the impact of all collected waste being sent to a municipal incineration facility, whilst scenarios 5a-5c model the impact of three levels of increased recycling rates, without changing the disposal destinations and proportions of non-recycled MSW.

There are also additional environmental benefits and burdens associated with some of the scenarios that have not been modelled in the current study, which focuses on GWP impacts, but which would be relevant to policy making. The additional benefits include biogas production from anaerobic digestion and energy recovery from municipal waste incineration, whilst additional burdens include various negative impacts to human health associated with open dumping and open burning of MSW.

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Table 3: Waste scenarios used for the life cycle impact assessment

Scenario name	Functional unit	Description
S1a: Business as usual (BAU) with open dumping	1 tonne of MSW	53.4% of MSW generated is collected and sent to unsanitary landfill, 22% is removed for recycling, 24.7% is uncollected and assumed to go to open dumping.
S1b: BAU with open burning	As above	53.4% of MSW generated is collected and sent to unsanitary landfill, 22% is removed for recycling, 24.7% is uncollected and burned in the open.
S1c: BAU with maximum collection	As above	78% of MSW generated is collected and sent to unsanitary landfill, 22% is removed for recycling and none is sent to open dumping or burning.
S2a: Composting 1	As above	384 tonnes, or 22.6% of total putrescible waste generated and 30.3% of that currently collected, is composted. S1a applies for all other MSW.
S2b: Composting 2	As above	All putrescible MSW currently collected is composted.
S2c: Composting 3	As above	All putrescible MSW currently generated is composted..
S3a: AD 1	As above	384 tonnes (29.5%)of putrescible waste generated sent to anaerobic digestion, S1a applies for all other waste generated.
S3b: AD 2	As above	All putrescible MSW currently collected goes to an AD facility.
S3c: AD 3	As above	All putrescible MSW currently generated goes to an AD facility.
S4: Incineration of all MSW collected	As above	All MSW currently collected and sent to unsanitary landfill is sent to municipal incineration facility without energy recovery. S1a applies to all MSW uncollected or removed for recycling.
S5a: Enhanced recycling 1	0.9 tonnes MSW	10% more of the total MSW generated is removed for recycling thus avoiding unsanitary landfill, open dumping or open burning. S1a applies to all remaining waste.
S5b: Enhanced recycling 2	0.8 tonnes MSW	20% more of the total MSW generated is removed for recycling thus avoiding unsanitary landfill, open dumping or open burning. S1a applies to all remaining waste.
S5c: Enhanced recycling 3	0.7 tonnes MSW	30% more of the total MSW generated is removed for recycling thus avoiding unsanitary landfill, open dumping or open burning. S1a applies to all remaining waste.

Results of impact assessment

The results of the life cycle impact assessment, which are presented in Figure 2, show that the alternative scenarios associated with improved waste management could lower GWP impacts by up to 30% compared to BAU with open burning and by up to 37% compared to BAU with open dumping. The one qualification to these results is that scenarios 1-4 all represent GWP impacts of one tonne of MSW, whereas scenarios 5a-5c represent GWP impacts of less than one tonne of MSW, as the quantity of MSW removed for recycling is not considered in the analysis. Therefore the GWP values shown on Figure 2 for scenarios 1 - 4 can be treated as dimensionless embodied carbon coefficients for each scenario, e.g. S1a can be interpreted to mean that the disposal under this scenario of one tonne (or one kilogramme) of MSW in mass would be associated with 1.65 times that value in CO_2e emissions if measured in the same units.

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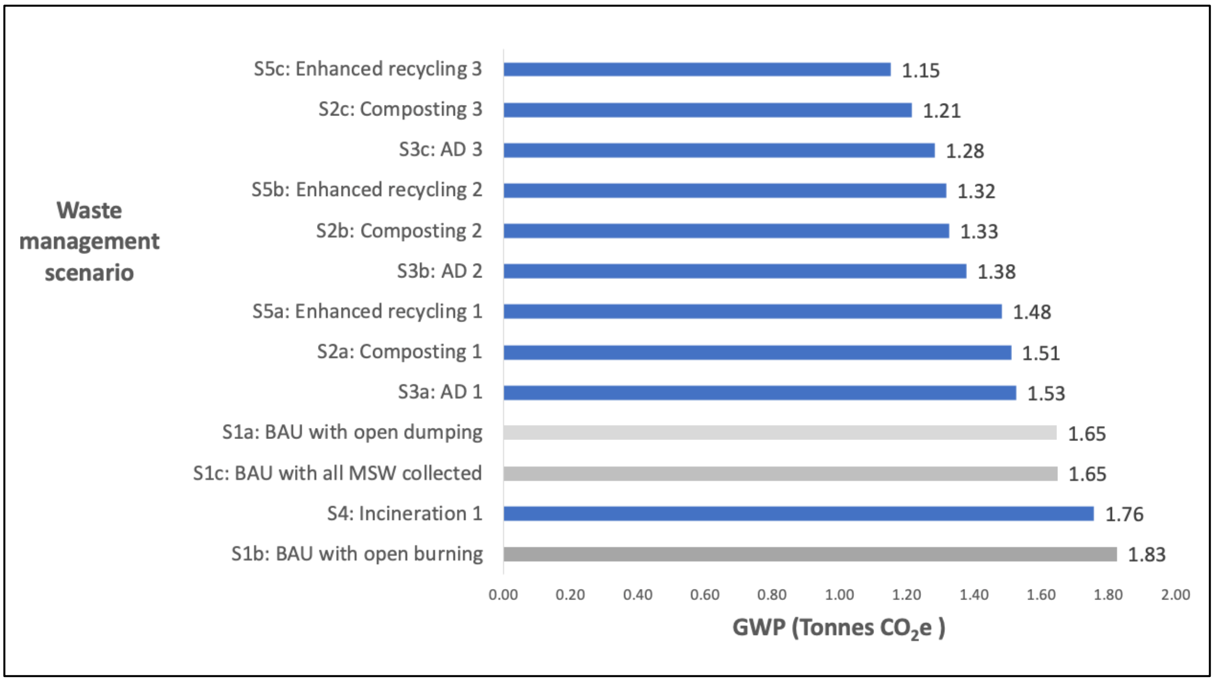

Figure 2: GWP impacts of alternative waste management scenarios for 1 tonne of MSW in Nairobi
(Note: BAU scenarios are indicated by grey shading)

Before discussing the results of the impact assessment, it should be noted that disposal of collected MSW at the Dandorah dumpsite is modelled in the various scenarios as 'unsanitary landfill', a category used in multiple waste management datasets within the Ecoinvent v3.8 database (Ecoinvent, 2022). This choice is informed by the UN report (2019), in which Dandorah's level of control is categorised as 'level 2', the second lowest on a 5-point quality scale, a level that features 'some waste compaction' but 'no cover', 'no leachate control' and 'some fire/smoke existence'. Similarly, the unsanitary landfill datasets within Ecoinvent are described as featuring untreated leachate and having 100% of landfill gas directly emitted (Ecoinvent, 2022). The scenarios used for the impact assessment do not include any in which the landfill site used is assumed to have achieved greater levels of control, as this is probably beyond the scope of waste management options likely to be implemented in the short term.

Key features of the impact assessment results shown in Figure 2 are as follows:

- The negligible difference between impacts of S1a and S1c indicates that sending the total amount of MSW generated (minus waste sent to recycling) to unsanitary landfill instead of open dumping would not lower GWP emissions at all. In fact, GWP emissions are marginally higher from an unsanitary landfill than from an open dump, because the relatively greater depth of compacted organic material in the landfill leads to more methane emissions from anaerobic degradation than would be associated with a shallower open dump (Ziegler-Rodriguez et al, 2019, Jensen and Pipatti, 2000). However, this difference is arguably offset by the greater environmental risks to human health associated with the likelihood that open dumps may be closer to residential areas and water sources which can become contaminated (Espinoza Perez et al, 2021).

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- Open burning of putrescibles under S1b is associated with the highest GWP impacts out of all the scenarios, whereas composting or anaerobic digestion of putrescibles under S2c and S3c is associated with the second and third lowest GWP impacts out of all scenarios. This confirms the sensitivity of various disposal options for all MSW generated to the choice of disposal destinations for the putrescible component, which makes up 57% of mass of MSW generated.
- Municipal incineration of all MSW currently collected, if facilities were available, under S4, would lead to GWP emissions 7% higher than sending collected waste to unsanitary landfill under S1a, with unchanged amounts of uncollected MSW sent to open dumping and MSW removed for recycling in both cases.

Conclusions

Overall, these results suggest that knowledge of the GWP impacts of various waste management scenarios can complement the implementation of DGM software by highlighting some of the benefits and disbenefits of possible scenarios enabled by use of the software. To inform policy, it is recommended that these results are combined with additional information on the economic and energy-related benefits of scenarios such as anaerobic digestion and municipal incineration, as well as the relative disbenefits for human health of open dumping, open burning and unsanitary landfill, all three of which disposal routes exist within the current practice of MSW management in Kenya.

For a more granular level of guidance on the GWP impacts of alternative waste disposal options as applied to each material type within the waste stream, the dimensionless individual coefficients for GWP impacts of each material and each disposal option used in this study are presented in Table 4. The GWP impacts of disposing of one tonne of a particular material identified in any column by a particular disposal option can be estimated by multiplying 1 tonne by the value found in each row corresponding to that disposal option. In using this data it should be considered that the relative values of GWP coefficients per material must be balanced against the proportion of total MSW mass made up by each material in evaluating the significance of total GWP impacts – e.g. biowaste disposal may have relatively low GWP coefficients compared to disposal of some other materials, but if most of the MSW stream is made up of biowaste, the choices made for biowaste disposal will be significant.

Table 4: Dimensionless GWP coefficients for MSW disposal options by material type

	MSW by material type									
Waste disposal options	**Biowaste**	**PP**	**PET**	**Paper**	**LDPE**	**Glass**	**Textiles**	**Wood**	**Steel**	**WEE**
Incineration	1.05	4.81	5.23	1.08	5.47	1.03	5.24	0.07	1.76	
Open burning		4.91	4.99	1.25	5.56	1.21		0.25		6.60
Open dumping	1.63	2.37	2.94	3.06	2.58	1.02		0.14		
Unsanitary landfill		2.41	2.98	3.90	2.63	1.02	1.62	0.15	0.75	
Anaerobic digestion	1.13									
Composting	1.03									

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