Turning organic waste into a socio-economic resource: A case study of the City of Windhoek, Namibia

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ABSTRACT

Management of municipal solid waste (MSW) is a major problem, especially in large cities in developing countries (DCs) and the City of Windhoek in Namibia is no exception. The main contributing factors to the problem are rapid population growth and economic advancement which increases the generation of solid waste. Approximately 63% of the MSW in Windhoek is organic and its inadequate management could result in enormous impacts on the environment, economy and health of the people. These include emission of greenhouse gases (GHGs) e.g. methane which is known to contribute to climate change; pollution of soil, air and water; public health impacts, and waste of usable resources. This study quantified the social, economic and environmental benefits that can be derived from aerobic processing of the organic fraction of MSW (OFMSW) in Windhoek. Data was gathered through literature review, interviews and observations. Results from this study show that aerobic processing of OFMSW in Windhoek can successfully recover resources such as organic fertilisers (20 000 tons/annum), reduce GHGs emissions (66%) and the volume of waste to be landfilled (62%). It also has the potential to create employment for approximately 200 of the urban poor, and generate approximately US$ 3 million in revenue annually. The study further highlights challenges such as lack of business plans and source segregation of organics which need to be addressed to ensure success of composting initiatives.

Key words: composting; municipal solid waste, Namibia, organic fraction, Windhoek

INTRODUCTION

Management of municipal solid waste (MSW) is a problem, especially in large cities in developing countries (DCs). The main contributing factors to the problem are rapid population growth and economic activities which increase the generation of solid waste (SW). Inappropriate waste management results in negative environmental effects such as water pollution and greenhouse gas (GHGs) emissions contributing to climate change (Koufodimos and Samaras, 2002; Mbuligwe *et al.*, 2002; UNESCAP, 2009). However, alternatives for managing the organic fraction of municipal solid waste (OFMSW) have emerged such as aerobic (e.g. composting) or anaerobic processing which have various advantages. Composting, for example, allows for recovery of resources and reduces GHGs emissions.

In cities such as Windhoek, Namibia a lot has been done to ensure proper waste management, especially considering that Windhoek is known as one of the cleanest cities in Africa (CoW, 2010a) which is a status that residents carry proudly and have to protect. Currently the collected SW from Windhoek is landfilled at Kupferberg landfill, located approximately 11 km southwest of the city.

Despite the efforts by the City of Windhoek, studies on aerobic processing of OFMSW are scarce and there are no known and documented existing composting initiatives of OFMSW in Windhoek. Hence, this study quantifies the social, economic and environmental benefits that can be derived from aerobic processing of the OFMSW in Windhoek.

STUDY AREA

Windhoek is the capital city of Namibia, located in Southern Africa and has a population of 325858 (NPC, 2012). The population growth rate in Windhoek is 4.4%, contributing to an increase in waste production and pollution, which further threatens the environment (Hasheela, 2009). Windhoek has an average temperature of 19.3^{o}C (winter in 6^{o}C and 31^{o}C in summer:), humidity of 32.7% and mean annual precipitation of 360 mm per annum.

MATERIALS AND METHODS

Data collection methods

Information and data for the study was obtained through literature review, interviews and focused group discussions with employees of the Solid Waste Management Division (SWMD), City of Windhoek. In addition, in-depth analyses of SWM case studies from other DCs and the lessons learnt were used to quantify the potential social, economic and environmental benefits of aerobic processing of OFMSW in Windhoek.

Data analysis methods

The first step in analysis of data was the development of three SWM scenarios for Windhoek:

- *Scenario A*: 100% of the OFMSW in Windhoek is landfilled and zero composted for 20 years. This served as the baseline scenario.
- *Scenario B*: 90% of the OFMSW in Windhoek is composted and 10% is landfilled for 20 years.
- *Scenario C*: The amount of OFMSW landfilled reduces by 18% every five years, increasing the amount of OFMSW composted by 18% every five years for 20 years.

For each of these scenarios, GHG emissions were calculated for a period of 20 years using equation 1 – 4. The amount of organic waste used as base data in this study was 67 000 tons/a (63% of solid waste generated in Windhoek), which is a waste generation figure for 2010. This is the estimate sum of all the organic waste generated in Windhoek: 15% organic waste; 32% garden refuse; 1% wood and 15% paper (Hasheela, 2009). The underlying assumptions and data used in calculations are as follows:

- Approximately 67,000 tons/a of OFMSW is landfilled in the first year, 2010 (CoW, 2010b) and thereafter, SW generation in Windhoek increases by 3% per annum.
- Approximately 26%is the share of organic waste that degrades under anaerobic conditions in the composting plant per year. This was used to calculate methane generation from composting OFMSW per annum.
- Of the total quantity of OFMSW composted, 33% is converted to stable compost. This is based on Mansoor (2004) who indicated that for every three tons of organic waste composted, one ton is converted into stable compost.

For the conversion of methane emissions into GHGs emissions, the Global Warming Potential (GWP) of methane was assumed to be 21 tCO_2eq/ton CH_4(UNFCCC/CCNUCC, 2008b). The type of landfill used is a modern landfill with impermeable lining at the bottom.

Equation 1: GHG Emissions from composting ($PE_{c,y}$).

$$PE_{c,y} = PE_{c,N2O,y} + PE_{c,CH4,y}$$

Where:

$PE_{c,N2O,y}$ Is the N_2O emissions during the composting process in yeary (tCO_2e).

$PE_{c,CH4,y}$ Is the emissions during the composting process due to methane production through anaerobic conditions in year y (tCO_2e).

Equation 2: N_2O emissions from composting ($PE_{c,N2O,y}$).

$$PE_{c,N2O,y} = M_{compost,y} * EF_{c,N2O} * GWP_{N2O}$$

Where:

$PE_{c,N2O,y}$ Is the N_2O emissions during the composting process in year y (tCO_2e).

$M_{compost,y}$ Is the total quantity of compost produced in year y (tonnes/a).

$EF_{c,N2O}$ Is the emission factor for N_2O emissions from the composting process (tN_2O/t compost). A default emission factor is 0.043 kg N_2O per tonne of compost for $EF_{c,N2O}$.

GWP_{N2O} Is the Global Warming Potential of nitrous oxide, (tCO_2/tN_2O. Default value 310 ton CO_2eq/ton N_2O.

Equation 3: CH_4 emissions from composting ($PE_{c,CH4,y}$).

$$PE_{c,CH4,y} = MB_{compost,y} * S_{a,y}$$

Where:

$PE_{c,CH4,y}$ Is the project methane emissions due to anaerobic conditions in the composting process in year y (tCO_2e).

$S_{a,y}$ Is the share of the waste that degrades under anaerobic conditions in the composting plant during year y (%).

$MB_{compost,\ y}$ Is the quantity of methane that would be produced in the landfill in the absence of the composting activity in year y (tCO_2e). Mbcompost,y is estimated using equation 4 below.

The GHGs generation and emissions from landfilling of the OFMSW in Windhoek were quantified using equation 4 below. This is a UNFCCC/CCNUCC (2008a) tool for GHGs prognosis which is based on a first order decay model of organic matter. The tool is to be used for the prediction of GHGs generation and approval of Carbon Development Mechanisms (CDM) projects.

Equation 4: Amount of methane produced from landfilling ($BE_{CH4,SWDS,y}$).

$$BE_{CH4,SWDS,y} = \emptyset.(1-f).GWP_{CH4}.(1-OX).\frac{16}{12}.F.DOC_f.MCF.\sum_{x=1}^{y}\sum_{j}W_{j,x}.DOC_j.e^{-kj.(y-x)}.(1-e^{-kj})$$

Where:

$BE_{CH4,SWDS,y}$	Methane emission avoided during the year y from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year y (tCO_2e).
Φ	Model correction factor to account for model uncertainties (default 0.9).
OX	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste).
F	Fraction of methane in the SWDS gas (volume fraction) (default 0.5).
DOC_f	Fraction of degradable organic carbon (DOC) that can decompose (default 0.5).
CR	Landfill gas collection rate.
MCF	Methane correction factor.
$W_{j,x}$	Amount of organic type j prevented from disposal in the SWDS in the year x (tons).
DOCj	Fraction of degradable organic carbon (by weight) in the waste type j.
k_j	Decay rate for the waste type j
j	Waste type category.
x	Year during the crediting period: x runs from the first year of the first crediting period (x = 1) to the year y for which avoided emissions are calculated (x = y).
y	Year for which methane emissions are calculated.

Economic benefits of aerobic processing of OFMSW in Windhoek were quantified by calculating the total revenue from the sale of compost and Carbon Emission Reductions (CERs) generated from composting 90% of the OFMSW in Windhoek and revenue from door-to-door collection of 90% of the OFMSW in Windhoek. Overall, the Net Present Value (NPV) (an indicator of profitability or loss) for composting 90% of the OFMSW in Windhoek was also calculated. The economic benefits of aerobic processing of OFMSW in Windhoek were determined using a number of assumptions, based on the lessons learned from existing composting plants in DCs:

- The consumers in Windhoek pays for waste collection, resulting in earning of 3,215,000 US$/a (large scale plant) and 3,108,000 US$/a (small to medium scale plants).
- The investment cost for a large scale composting plant with a capacity of 170 tons/a is 510,000 US$ and for 57 small to medium scale composting plants each with a capacity of 3 tons/day is400,000 US$.
- The operational costs per annum are: 215,000 US$ for a large scale plant and 195,000 US$ for all 57 small to medium scale plants.
- The discount rate is 8%.
- The project lifespan is 5 years.
- The calculations on NPV assumes that the revenues are constant over the calculated period (5 years). In reality the collection fees might increase over the years or the number of households served might vary. Furthermore, the compost prices might also require adjustments to accommodate the market fluctuations.

Lastly, the social benefits were quantified by determining the employment opportunities from composting 90% of the OFMSW in Windhoek. These values were calculated based on the lessons learned from analysed composting plants in DCs as well as the existing number of waste collectors employed by the CoW (Korner and Visvanathan, 2007; Mansoor, 2004; Rothenberger and Zubruegg, 2006).

RESULTS

Environmental benefits

Reduction of GHGs emissions - the analysis revealed that composting 90% of the OFMSW (61000 tons/annum) in Windhoek would reduce the overall quantity of waste that ends up in the landfill by 62% (163 000m^3/a) (Figure 1). Subsequently, reducing the GHGs emissions (CH_4) from landfilling.

*Scenario A (Baseline)*shows an increase in GHGs generation and emissions per annum (Figure 1). The GHG generation increases over time, due to continuous landfilling of organic waste which is influenced by the population growth. Thus, GHGs (mainly CH_4) continues to escape into the atmosphere.

Comparing *Scenario A* and *B* (Figure 1), the results show that Scenario B significantly reduces GHGs emissions by 66% (335 621 tCO_2eq). The projected GHGs emissions in 2030 for Scenario A is 503 838 tCO_2eq/a, whereas for Scenario B is 168 217 tCO_2eq/a. However, it should be noted that the decrease in emissions is only partially compensated by the increased generation of N_2O during the composting process (Rotter *et al.*, 2009).

Scenario C illustrates how the target of 90% composting of OFMSW (in scenario B) can be achieved. In this scenario, the amount of OFMSW landfilled reduces by 18% every five years over a period of 20 years, while the amount of OFMSW composted increases by 18% every five years until the target of 90% composting of OFMSW is reached (Figure 2). In addition, it presents the total GHGs generated and emitted during the 20 year period. Figure 2 shows a gradual increase in GHGs emissions from landfilling. The gradual increase is due to the 3% annual increase in organic waste generation. After the 20th year when only 10% of OFMSW is landfilled the GHGs emissions from landfilling reduces, due to the reduced quantity of waste that is landfilled. On the other hand the GHGs emissions from composting will gradually increase, because more waste is diverted for composting every five years.

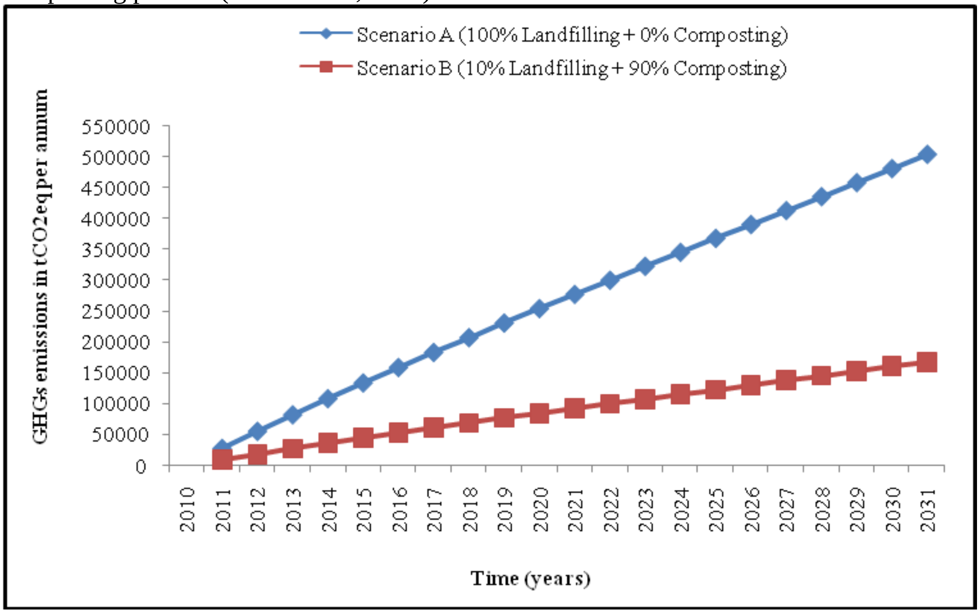

Figure1. A comparison of GHGs emissions from scenario A (100% Landfilling + 0% Composting) and B (10% Landfilling + 90% Composting)

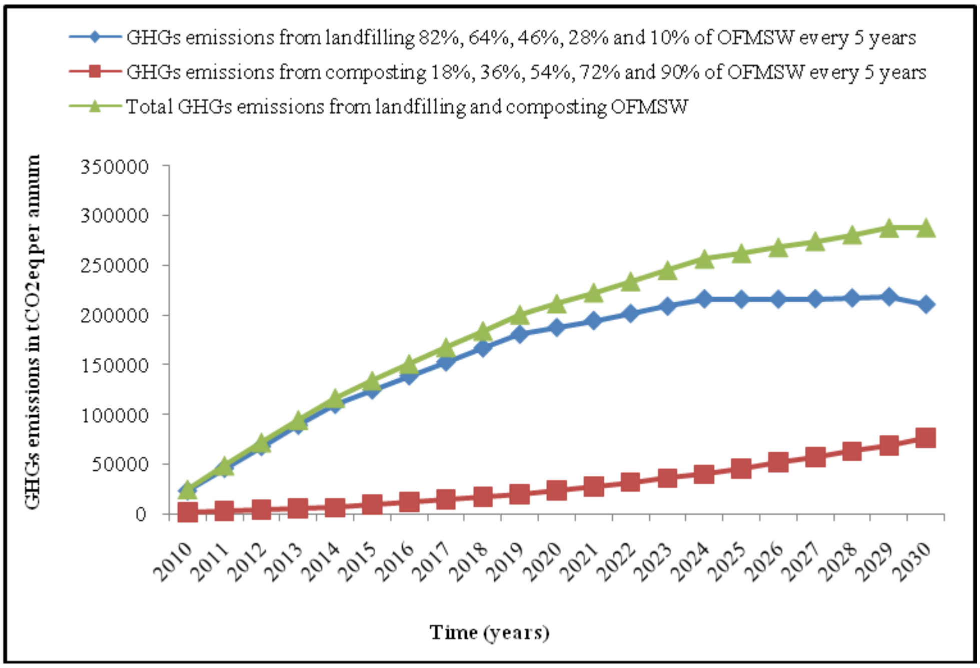

Figure2: An illustration of GHGs emissions from gradual reduction of landfilling and gradual increase in composting of OFMSW by 18% every 5 years

Reduction of Nitrogen, Phosphorus and Potassium (NPK) loads from chemical fertilisers - On an annual basis, approximately 46 000 tons of chemical fertilisers are imported into Namibia (NPC, 2010). Assuming that all these fertilisers are applied on agricultural soils in Namibia, they contribute to increased accumulations of NPK in the soils every year. Application of compost from OFMSW (20000 tons of compost/a) in Windhoek can substitute the NPK contribution by chemical fertilisers on agricultural soils by 21% (N), 9% (P) and 6% (K). The calculations were based on the following:

- Chemical fertilisers contain N (2%), P (3%) and Potassium (4%) (NPC, 2010).
- Compost produced from OFMSW in Windhoek per annum contains N (1%), P (0.6%) and K (0.6%) (Mansoor, 2004).

Economic benefits

The NPVs for both the large scale and small to medium scale composting plants showed that the composting initiatives is financially viable, positive NPVs for large scale plant (11,474,000 US$) and for all the small scale plants (11,200,000 US$) were obtained. These indicate profitable composting initiatives, meaning that the composting initiatives will generate sufficient funds to cover all the costs and the expected repayments.

Social benefits

Composting of the 90% of OFMSW in Windhoek will provide employment to a total of 243 persons (large scale plant) or 171 persons (small to medium scale plants). Approximately 176,000 USS$/a (large scale plant) and 157,000 US$/a (small to medium scale plants) were estimated as the source of income for the workers.

DISCUSSION

The existing system for managing OFMSW in Windhoek is associated with odour problems, more land requirements for landfilling and GHGs emissions (CoW, 2010). This is also illustrated by the baseline scenario A which shows an annual increase of GHGs emissions (mostly $CH_{4)}$ released into the atmosphere. The results indicate that scenario B (composting of 90% of source segregated OFMSW and only landfilling 10% OFMSW in Windhoek) would possibly produce compost that can be used to improve the soil quality of agricultural fields, reduce the volume of waste disposed off at the Kupferberg landfill, reduce GHGs emissions, generate employment and revenue.

Although both the centralised large scale composting plant and the decentralised small to medium scale composting plants returned positive NPVs, the latter might be more suitable for Windhoek. This is mainly because decentralised small to medium plants would allow for re-use of organic waste at the site where it is generated, thus minimising collection and transport costs and consequently reducing the operational costs. This would be ideal, especially considering the transport challenges that the existing recycling companies in Namibia are already facing. Nonetheless, there is no one "right answer" instead there are several possible options that could be explored.For example a combination of a centralised large scale composting plant and decentralised small to medium scale composting plants would also be ideal.

Successful composting presents challenges compared to the baseline scenario. It requires awareness and public education on source segregation and composting in general. According to Rotter *et al* (2006), producing clean compost is often difficult, because keeping the organics clean through source segregation is difficult. This is due to ignorance, poor understanding and lack of awareness on composting and its benefits. Although source segregation of organics is beneficial for composting, it can increase the costs of SW collection (Rotter *et al.*, 2009), because source segregated waste requires collection vehicles with compartments and an increase in the number of collection bins. Furthermore, it requires cooperation among the various stakeholders involved in SWM and development of laws and policies that will guide implementation of composting initiatives. Most importantly, the success of the composting initiative/s will depend on the market for compost and the public acceptance of compost.

CONCLUSION AND RECOMMENDATIONS

The study demonstrated that aerobic processing of OFMSW has a huge potential in Windhoek, yielding environmental, economic and social benefits. However development of appropriate business plans for composting initiatives will be crucial and may be the key to successful and viable composting initiatives. Such plans will guide all phases of the composting initiative, including the marketing of the final compost product. The development of markets for compost be considered from the beginning of the composting initiatives, thus ensuring successful operation of viable composting initiatives. This could possibly be done through involvement of the private sector such as fertiliser marketing companies, complemented by awareness raising. Secondly, implementation of awareness raising programmes and environmental education on composting i.e. its benefits and source segregation of organics is imperative. Source segregation of SW can be stimulated through provision of incentives. This would entail that consumers only pay for residual waste collection such as mixed MSW, whereas, source segregated organic wastes and recyclables are collected at no cost to the consumer. In this way more effective source segregation results in lower fees, thus encouraging consumers. On the other hand, it ensures that clean organics are used as input materials, consequently resulting in compost of high quality.

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