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Implementing separate waste collection and mechanical biological waste treatment in South Africa: A comparison with Austria and England

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abstract

The degradation of organic compounds found in municipal solid waste (MSW) under the anaerobic landfill conditions produces gas and liquid emissions that can protract well into the landfill after-care period. The European Landfill Directives regulate the amount and nature of the organic compounds disposed into landfills. In South Africa and other developing countries, MSW is still landfilled without any kind of pretreatment. This paper presents a pilot project of mechanical biological waste treatment (MBWT) in South Africa implemented at municipal level in the city of Durban using passively aerated open windrows. Based on case studies from Austria, England and South Africa, a waste minimisation model which can facilitate full-scale implementation of MBWT in developing countries is presented. MSW was treated in open windrows for 8 weeks. Composting temperature reached a maximum of 65 C in less than 10 days. The results of eluate tests on waste samples from the windrows at the end of composting show a reduction of BOD_5 and BOD_5/COD ratios equal to 35.7% and 16.7%, respectively. The percent waste composition of the treated MSW was 28.3% putrescibles, 17.4% garden refuse, 13.3% plastic, 12.4% fabrics, 12% paper and other elements. The waste composition shows that more than 40% of un-treated organic material and also more than 40% non-biodegradable and recyclable materials are still landfilled without any form of biological treatment or resource recovery. A simple wet and dry waste collection model can promote recycling, treatment of biological waste before landfilling, resource recovery, labour intensive jobs and hence sustainable landfilling in the South African scenario as well as in similar developing countries.

1. Introduction

The decomposition of organic compounds under anaerobic landfill conditions develops through four phases, namely: aerobic (I), anaerobic non-methanogenic (II), anaerobic methanogenic unsteady (III) and anaerobic methanogenic steady (IV) (Farquhar and Rover, 1973). The length of these phases, as well as the after-care period needed after closure of the landfill, are highly variable and authors have proposed various time frames. Typically ‘‘after-care period” refers to the time after closure of the landfill when the landfill operators are still responsible for the control, management and treatment of the emissions associated with degradation. This period is regulated in South Africa by the South African Minimum Requirements for Disposal by Landfill and can be as high as 30–50 years (DWAF, 1998). To minimise the economic burden associated with the after-care period and reduce its environmental impact, waste managers are developing methods to accelerate waste stabilisation.

Waste degradation processes in landfills depend on factors such as the initial waste composition, rate of disposal, presence of separate collection and climatic conditions.

In the European Union, there has been a gradual change of legislation governing waste disposal to landfill. The movement towards a ‘‘sustainable” landfill has led to new developments in waste legislation towards the introduction of waste treatment prior to disposal. Member states of the EU have targets to reduce he biodegradable fraction of MSW by 25%, 50% and 65% during the years 2006, 2009 and 2016, respectively (Stegmann, 2005; Slack et al., 2009).

In South Africa and other developing countries, waste legislation is still focused on the ‘‘concentrate and contain” approach whereby un-treated and unsorted waste is disposed in lined sanitary landfills equipped with biogas and leachate extraction systems (Trois et al., 2007). During the first South African Waste Summit the Polokwane Declaration which sets reduction goals in both waste generation and waste disposal of 50% and 25%, respectively, by 2012 and a full zero waste plan by the year 2020, was signed in 2001. So far, none of the largest municipalities seems to be in line to achieve these very optimistic objectives, although

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various solutions are being investigated and implemented at pilot scale level.

In Durban, the third largest city in South Africa, the first South African mechanical biological waste treatment (MBWT) pilot project was initiated at the Bisasar Road landfill site in 2002, in collaboration with Durban Solid Waste (DSW – the municipal disposal unit), the Technical University of Dresden and Tswhane University of Technology. The aim of the project was to identify suitable techniques for waste treatment in local municipalities and peri-urban settings. The Dome Aeration Technology (DAT) that promotes waste composting in passively aerated windrows was found to be suitable because of its low costs, zero/low energy input during the composting period, potential for labour intensive operations, adaptability to local weather conditions and reduced machinery requirements (Trois et al., 2007).

The DAT was originally developed by the University of Technology in Dresden in order to solve problems of aeration and influence of weather during the aerobic treatment of waste (Mollekopft et al., 2002). The full-scale implementation of the DAT is mainly dependent on the method of waste collection and the characteristics of the waste streams. Current research indicates the following benefits associated with waste pre-treatment: reduction of weight and volume; reduction of water content; meeting hygienic requirements; reduction in biodegradable components; biological stabilisation; reduction of gas formation potential; reduction of leachable components; increased particle grain size; increased bulk density; and reduction of hydraulic conductivity (depends on density) (Pan and Voulvoulis, 2007).

This note reports on the second phase of the Durban pilot-project set up to study the possibility of large-scale implementation of MBWT under local conditions (Trois et al., 2007) and compares proposed waste minimisation schemes for South Africa, with current waste treatment strategies adopted in Austria and England, where MBWT prior to disposal is mandatory.

2. MBWT pilot project in South Africa

Durban, located on the eastern coast of South Africa, is part of the Greater eThekwini Municipality (5 million inhabitants) and the largest city (population 3.5 million) and producer of solid waste in the province of KwaZulu Natal. The region receives annual average rainfall of 1009 mm. The monthly temperatures range from the average maximum of 28 °C in January and February, to the average minimum of 11 °C in June and July. The highest and lowest recorded temperatures are 40 °C in October and 3 °C in July and August.

The high rainfall results in the generation of large volumes of leachate and accelerated biogas production from landfills (Trois et al., 2007). The significant generation of landfill emissions motivates for the implementation of a mechanical biological treatment step to landfilling operations in the region, and directed the decision to base the research in Durban. Moreover, in terms of waste management practice and available technology, landfilling operations and design, systems for control and treatment of landfill emissions, waste legislation and institutional framework surrounding the decision making process at municipal level, as well as waste composition and production rate, Durban (eThekwini) could be considered representative of large municipalities in South Africa, Africa and other emerging countries.

The city hosts four active sanitary municipal solid waste (MSW) landfills, operated by DSW and two hazardous waste sites that are privately owned. The pilot project was carried out at the Bisasar Road Landfill Site which, established in 1980, is situated approximately 8 km north of the Durban central business district. The landfill serves approximately 2 million people, covers an area of 44 ha and currently occupies approximately two thirds of the projected airspace of 21 million cubic meters. Bisasar Rd receives an average of three thousand tons of general MSW per day with waste compaction density between 1.0 and 1.4 t/m^3 achieved (Bowers et al., 2002; DWAF, 2005) The site is operated in fully engineered (lined) cells, equipped with leachate and biogas extraction systems over an old unlined waste body.

3. Materials and methods

Waste treatment was performed in three full scale passively aerated windrows (30 m long, 10 m wide and 2.5 m high) for 8 and 16 weeks during typical winter and summer months (a first set of two windrows was constructed at the beginning of April and dismantled at the end of July, after a period of 16 weeks. The third windrow was constructed in mid September and dismantled in mid November, after a period of 8 weeks). In previous studies (Paar et al., 1999; Mollekopft et al., 2002), the mechanical pre-treatment included sorting of the waste to separate the putrescibles from the non-biodegradable matter, shredding in a low-speed shredder/commuinutor, mixing of the waste fraction with structural material (e.g. woody waste) and wetting. Suitable shredder and mixer were not available for these trials, therefore appropriate alternatives had to be employed to ensure an adequate level of pre-treatment. The windrows were constructed using locally available machinery and were filled with a mixture of MSW and dry timber planks and branches (structural material – SM), and insulated with pine bark. The woody waste provided a structure to the compost heap thus allowing for good circulation of air. The MSW and the SM were mixed at a ratio of 2:1 (MSW:SM) and kept at an average moisture content of 55–65% for optimal microbial activity (Trois et al., 2007). From experience in other studies, moisture content can drop from 55% to 35% in 180 days, without any intermediate addition of water during the composting process (Paar et al., 1999). To achieve the recommended moisture content of 55%, 20 m^3 of water were added to 80 m^3 of waste assuming a Loose Bulk Density of 0.5 t/m^3. According to Münnich et al. (2006) intensive and evenly distributed watering of the windrows is necessary in order to ensure adequate moisture content for biological processes during the summer months with high evaporation rates. To maintain the correct amount of moisture and avoiding desiccation, due to high temperatures and dry summer, Windrow 3 was irrigated. The input material was typical MSW that is disposed daily at the Bisasar landfill site from ROTOPRESS trucks, that were preferred to other general collection vehicles because they comminute the waste on route, delivering well mixed and partially shredded material. The MSW was mixed with structural material on an articulated dump truck (ADT) using an excavator. Further mixing was performed when the ADT offloaded the mixture onto a prepared site. The spread shredded and mixed waste was then wetted using a 22 m^3 water tanker that repeatedly passed over the waste wetting and achieving further crushing and mixing.

A summary of the machinery that was used to construct the windrows and the operation steps is presented in Table 1, while Figs. 1 and 2 show typical dimensions of a windrow with 5 domes.

Table 1
Summary of windrow construction activities.

Operational steps	Machinery used
Mixing	Excavator and a tipping truck
Wetting	Water tanker
Placing mixture	Front-end loader
Covering windrow	Front-end loader/labourers

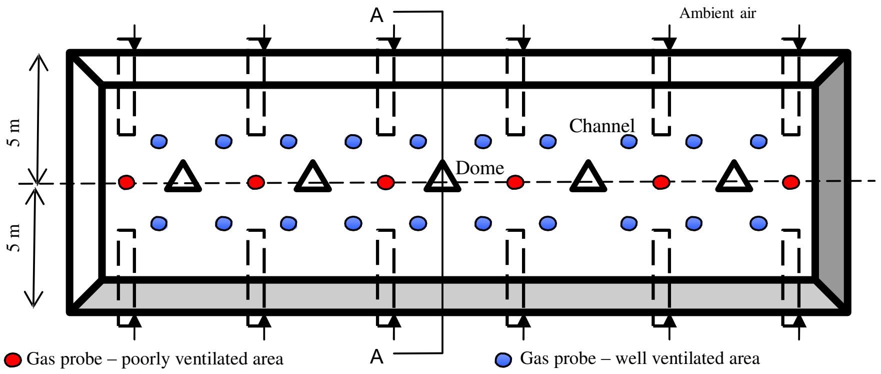

Fig. 1. The plan view of a typical windrow used at Bisasar Rd landfill.

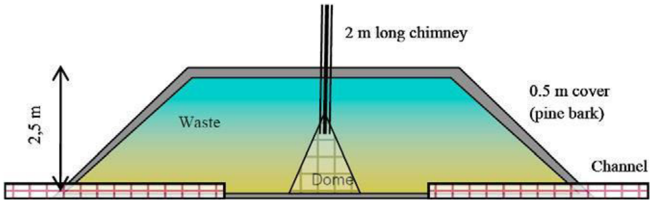

Fig. 2. The cross-sectional (A–A) view.

The performance of the windrows was monitored by recording the temperature variations during composting in the waste body and in the exhaust gases as well as gas flow and composition from the chimneys. Gas flows and composition were measured using an anemometer and a gas analyzer (Type GA2000), while temperatures were measured using a Major Tech MT-630 thermocouple. The position of gas and temperature testing probes is presented in Fig. 1.

Input and output windrow materials were characterised to determine waste composition, biological activity and the efficiency of the process. The output material was sieved in a 5 mm aperture sieve and characterised to establish the nature of fine and coarse fractions. The tests were conducted on eluates and solid matter. The eluate tests were conducted in accordance with the European standards (EN 12457/2 & 4) by mixing distilled water and the solid waste in a liquid to solid ratio of 10:1 in a vessel for 24 h using an orbital sharker. The eluates were coarsely filtered using a Whatman 40 glass-fiber filter paper and tested for COD, BOD, NH_3, NO_3 and conductivity according to Clesceri et al., 1998. The solid waste matter was tested for total and volatile solids (TS and VS). Analyses were conducted in double or in triplicate for accuracy purposes.

4. Discussion of the results of the treatment trials

The windrows remained aerobic throughout the composting period and the concentration of oxygen ranged between 15.1% and 20.6% vol/vol. Fig. 3 shows a summary of the process parameters for windrow 3 (as this was similar to the other two windrows). The irrigation was followed by an average increase of 9.4 C in the composting temperature on day 40, to indicate that a possible inhibition of the biological activity took place as a result of the intense heating in the first 2 weeks of composting.

From Figs. 4–7, it can be observed that the landfilled MSW comprised of more than 40% of organic material, i.e. fine putrescibles which are less than 50 mm in diameter; and more than 40% of recyclable and non-biodegradable waste, which includes plastic, fabrics and paper is still disposed in South African landfills today.

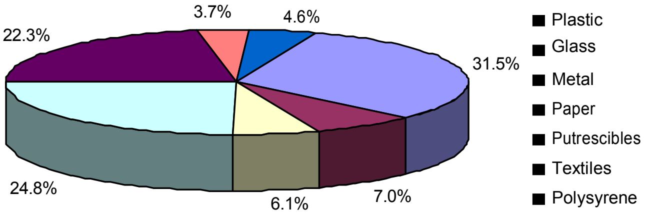

Fig. 4. Percentage composition of un-treated MSW used to fill the windrows.

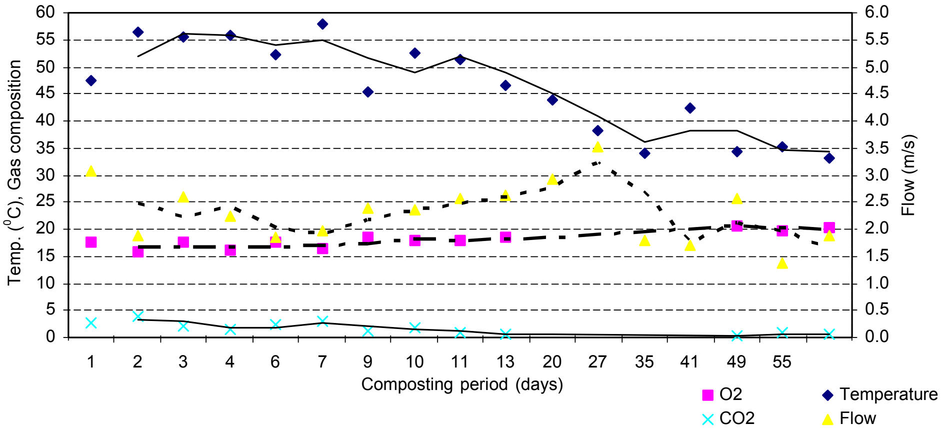

Fig. 3. Process parameters for windrow 3.

The DAT was effective in reducing the readily biodegradable organic component of the MSW. The efficiency of the DAT in stabilising the waste is presented in Table 2.

The percent reduction in BOD$_5$, BOD$_5$/COD ratio, conductivity and volatile solids in the eluates, suggests that the windrows were effective in reducing the readily degradable organic compounds contained in the MSW after only 8 weeks. During a comparative study carried out by Trois et al. (2007) the percent reduction in the BOD$_5$ was 43.6% after 8 weeks of composting. In a mechanical biological treatment (MBT) study executed in Brazil, the organic content of MSW was reduced by more than 90% after 450 days of composting (Munnich et al., 2006). The increase in the NO$_3$ concentration can be attributed to the oxidation of the organic nitrogen compounds found in the MSW as well as in the vegetable matter used as structural material in the windrows.

The findings of the pilot MBWT project suggest that open windrows could be considered as a suitable solution for municipalities in South Africa, but their efficiency can be increased by a selective separation of the slowly or non-biodegradable materials prior to pre-treatment. In order to efficiently incorporate MBWT into existing waste management systems at municipal level in South Africa, a literature review of available waste minimisation schemes in Europe was conducted and a ‘‘zero waste” model proposed to the local municipality. The following sections present the findings of a comparative study of waste management systems in Austria and England that mostly informed the design of the South African model for the city of Durban (Matete and Trois, 2008).

Table 2
MSW properties before and after 8 weeks of composting.

Parameter	Before composting	After composting	Percent reduction
COD (mg/l)	2269	1750	22.9
BOD$_5$ (mg/l)	1016	653	35.7
NH$_3$ (mgN/l/kgdm)	0.388	1.06	*Increase*
NO$_3$ (mgN/l/kgdm)	0.148	0.25	*Increase*
pH	6.37	7.13	*Increase*
Conductivity (mS/cm)	1.91	1.12	41
BOD$_5$/COD	0.448	0.373	16.7
VS (g/gdm)	0.701	0.449	35.9

dm: dry matter.

5. Waste management in England and Austria

The English waste strategy was set in the year 2000 to reduce landfill waste by recycling and composting. New technologies were developed to divert the biodegradable municipal waste from landfills including composting of biodegradable municipal waste (BMW), mechanical heat treatment (MHT) and incineration (Defra, 2006). According to the waste strategy annual progress report (WS2007/8 – Defra, 2007/8) of 2007/8 the following achievements have been realised between the years 2000/1 and 2006/7: residual waste has decreased by 22%, household recycling increased by 33%, total waste to landfill reduced of 20% and the amount of industrial

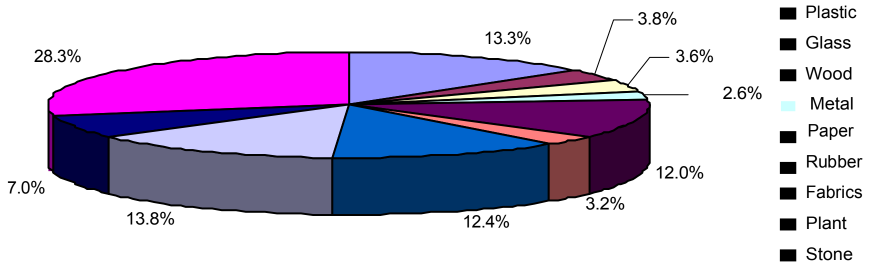

Fig. 5. Percent composition of treated waste (global sample).

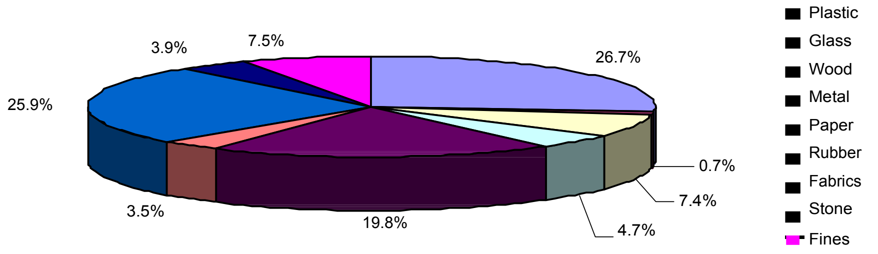

Fig. 6. Percent composition of treated waste retained on 50 mm sieve.

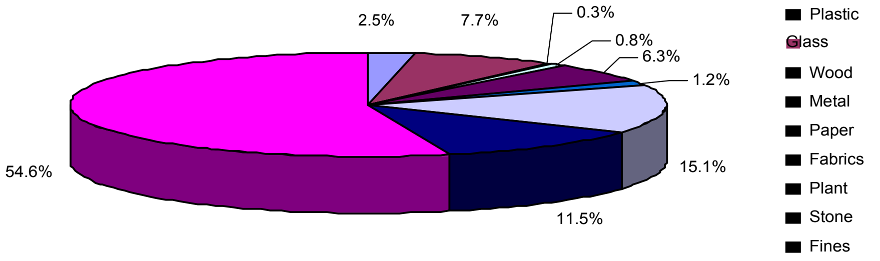

Fig. 7. Percent composition of treated waste passing through 50 mm sieve.

waste being sent to the landfill decreased by 23%. According to the WS2007/8 reduction in the volume of landfilled material is due to the governmental initiatives which include incentivizing waste reduction, re-use, recycling and energy recovery; diversion of waste from the landfill; and stimulating investment in collection, recycling and recovery infrastructure. The fundamental concept that allows for a consistent reduction of landfilled waste involves the implementation of a waste management strategy which is based on mixed and segregated collection. The mixed waste is either sorted, treated thermally or biologically before landfilling or disposed straight in the landfill. The segregated waste is either recycled or composted. A typical waste management model adopted in the England is presented in Fig. 8.

Like most of the European cities, the city of Vienna faces the problem of ever increasing volumes of municipal solid waste.

The Federal Waste Management Plan, which is derived from the Waste Management Act 2002, is based on the principles of waste prevention, waste recovery and waste disposal (BAWP, 2006). Waste from households and similar establishments are collected separately from residual/bulky waste. The dry component of the household is sorted for recovery and recycling whilst the biogenic portion undergoes sorting, biotechnical treatment and composting. The residual waste is either incinerated or undergoes mechanical biological waste treatment. The compost quality is monitored according to the Compost Ordinance, FLG II Nr. 292/2001. The ordinance gives three different quality classes for compost based on the content of heavy metals. The final composition of the landfilled material comprises of ash from incinerators, residual waste and non-recyclable waste materials.

6. A simple wet and dry model for South Africa

No separate collection is currently applied in the main South African municipalities, but garden refuse is disposed separately from general MSW. The findings of the comparative analysis suggest that a simple ‘‘wet and dry” separate collection model may be suitable at municipal level in South Africa and other developing nations, as presented in Fig. 9. In the ‘‘dry and wet” model, organic waste (food and yard waste) and garden refuse constitute the ‘‘wet” fraction which is generally collected separately from the ‘‘dry” recyclable fractions like plastic, paper/cardboard, cans, glass and scrap metal. After collection, the wet waste can be crushed to reduce particle size, mixed, corrected for moisture content and composted in open windrows or in in-vessel composting plants, or anaerobically digested to produce biogas.

The dry waste can be further sorted by hand in a transfer station or in a Material Recovery Facility situated directly in the premises of the landfill, so to reduce transport costs and avoid illegal recycling/scavenging. The mixed/residual and other non-recyclable material should be landfilled. The ultimate products of the ‘‘wet and dry” model will be garden refuse compost, recyclables and mixed residues. There is an emerging market for garden refuse compost and recyclables in South Africa, while the mixed residues will have to be disposed in landfills (Matete and Trois, 2008).

The applicability of implementing the DAT in South African municipalities as an integral part of the ‘‘dry and wet” model was also evaluated in relation to implementation costs and space requirements.

The DAT composting process has specific space requirements and space availability can become a limiting factor in terms of the efficiency of the composting process. If space is at a premium, a shorter composting period should be adopted, although this should not fall below 8 weeks (Griffith, 2009).

The space required to run a full scale DAT operation at the Bisasar Road landfill site (based on a 30 m long, 11 m wide and 3 m high windrow plus 5 m between windrows for machinery access, for a total quantity of MSW and garden refuse of 510,000 t/year) was estimated to be 13.9 ha and 34.6 ha for a treatment period of 8 and 20 weeks respectively (Griffith, 2009). The total area footprint of the Bisasar Rd site is 44 ha; however, not all the space is suitable due to steep gradients. Thus implementation of a full-scale operation with an 8-week treatment period may be possible on site, while longer operations require alternative locations (Griffith, 2009).

Previous research suggested that investment and operational costs to set-up DAT windrows in landfills for emerging nations and developing countries could be estimated around 10–30 US$/t and 8–12 US$/t, respectively (Paar et al., 1999). Considering an approximate figure of €25/t of waste (1€ = 1.48US$ and 1€ = 11.24 SARand) and including the financial benefits derived by potential selling of CER (Certified Emissions Reductions) revenues

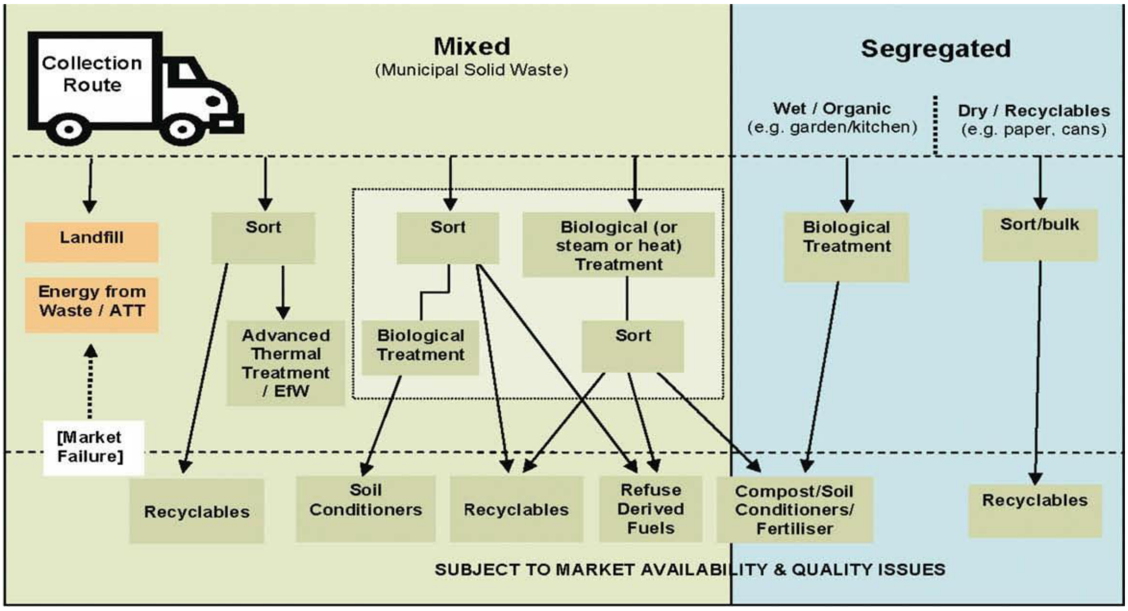

Fig. 8. Options for recovery and disposal of MSW in England (Defra, 2006).

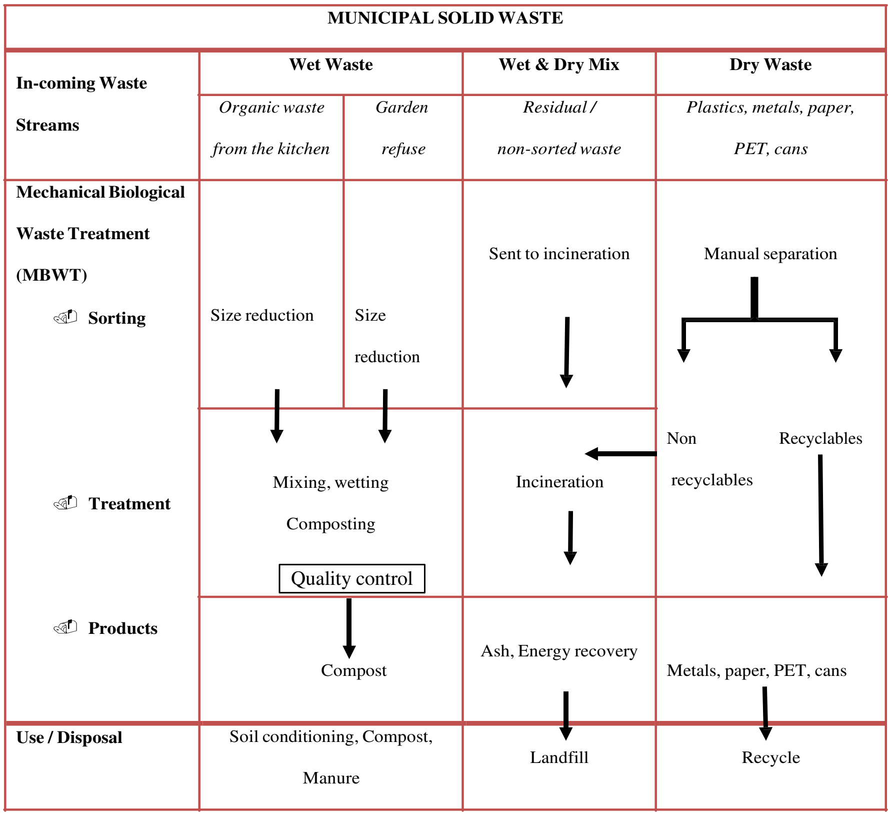

Fig. 9. Proposed separate waste collection model to promote MBWT in South Africa.

of €5.80/t of treated waste (through CDM – Clean Development Mechanism – estimated for 0.43 CERs/t of waste treated for an CER floor price of approximately €13.50/CER (www.pointcarbon.com)) and assuming 50% landfill savings due to pre-treatment as equivalent to 0.98€/t of cost savings, the total investment cost of implementation of a full-scale operation at the Bisasar Road Landfill Site would be approximately 9.8 M€ (R110 M).

Working at a rate of 60 t/day, the operational/construction costs were estimated as shown in Table 3.

7. Conclusions

Based on the results of the waste characterisation before and after composting, presented in Table 2, the pre-treatment proved to be efficient in reducing the easily biodegradable compounds in the MSW. The BOD_5, BOD/COD and VS were reduced of 35.7%, 16.7% and 35.9% respectively, after 8 weeks of composting. To avoid desiccation and slowing down in the rate of composting, irrigation of the windrows during months of high evapotranspiration is recommended. The MSW of 90% disposed to landfills in South Africa is still collected without any form of separation which results in the landfilling of 40% of un-treated readily biodegradable material, as well as some 60% of non-biodegradable/recyclable matter, thus negating the strive towards zero waste. If this practice continues, the landfill after-care period is less likely to be reduced, resulting in unsustainable landfills.

Table 3
Operational costs for the MBWT pilot project.

	for windrow construction	US$/ha	U$/t
Truck (ADT)	4	35	2.35
Front-end loader	1	45	0.75
20 Kl water tanker	2	30	1.00
Excavator	6	45	4.50
General labourers	8	2.5	0.35
Total		157.5	8.95

It can be learnt from the case studies presented in this note that separate waste collection, recycling and waste treatment prior to final disposal of the residues form the basis of a sensible waste management strategy for municipalities. The benefits of separate waste collection include reduction in waste generation, promotion of recycling, resource recovery, diverting waste from the landfill and eliminating scavenging. Finally, a simple ‘‘wet and dry” separation model is recommended for Durban (and similar municipalities in South Africa) to increase the efficiency of any type of waste treatment solution.

We believe that separate waste collection as well as waste treatment prior to disposal can not only fulfill the requirements for ‘‘zero waste” as stated by the Polokwane Declaration, but also can ultimately promote labour based activities and job creation in South Africa and in similar developing nations. On the other hand, the lack of ad hoc legislation in South Africa on waste pre-treatment should not be reason for an indiscriminate application of these methods.

We believe that the implementation of MBWT systems could become an essential feature of sustainable landfilling practices, particularly as a vehicle to promote waste minimisation and emis-

applicability of open windrow composting in relation to environmental and health issues associated with toxicity of exhaust gasses and leachates, as this was not considered in this study. Open windrow composting as well as separate collection in material recovery facilities should be implemented only in landfills so to fall under

South African Minimum Requirements (DWAF, 2005).

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