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Separation, sorting and composting of MSW at the Pugu dumpsite in Dar es Salaam

Report commissioned by ISWA on behalf of the Climate Clean Air Coalition Municipal Solid Waste Inititiave (CCAC MSWI)

ISWA International Solid Waste Association

CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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1. Introduction

Dar es Salaam's population is rapidly growing and is expected to reach 6,2 million by 2025. By that time the production of municipal waste will have grown from the present 6.000 tons/day to a possible 12.000 tons/day, assuming an annual growth rate of 10%.
Currently no more than a daily 1000 tons[1] reach the only disposal site in Dar: the Pugu Kyniamwezi dumpsite. It is located in the outskirts of Ilala, west of the international airport and some 30 km from the city center.

The Pugu-site is said to be running out of space; operations have reached the periphery of the location. A mission of Dutch SWM experts in september last year concluded that Pugu could still play an important role for many years to come provided:

- an overall remediation is implemented,
- operations are focusing on piling up the incoming waste, reaching heights of at least 40 m.,
- incoming waste is treated by sieving, sorting and composting in order to reduce the overall "consumption" of landfill space.

Figure 1. Hand drawing of the Pugu dumpsite

ISWA has been working in Dar es Salaam since December 2014 on behalf of the CCAC Municipal Solid Waste Initiative to provide capacity building for local authorities and other main stakeholders and conduct a pilot project on awareness raising for improved solid waste management. ISWA has commissioned BreAd with the task to elaborate the last bullet; the pre-treatment of incoming waste.

2. Objective, conceptual framework and deliverables

The objective of the study is to explore the potential benefits of Pugu-based installations and operations for the separation and sorting of recyclables from 100.000 tons/year of household waste and for composting the organic fraction. The conceptual framework is further defined by BreAd as follows:

- There will be 300 operational days per year with 10 operational hours per day and, within these constraints, a downtime of 15-20%.
- Sufficient space will be available at zero cost
- Open air operations are allowed; only the sorting activities will be placed under a roof
- The focus will be on maximum reduction of needed landfill capacity
- The focus will also be on including a maximum of the informal workforce of waste-pickers in formal jobs
- There will be options for including co-treatment of market waste

[1] "Expert mission on integrated solid waste management in Dar es Salaam", Dutch Ministry of Infrastructure and the Environment, MAT16TZ01, Report of findings, November 2016

- The composition of the household waste will be as defined in Figure 2 (this data was gathered in 2004 and is supposed to be valid at this moment and in the nearby future)
- The waste will not be collected in plastic bags.

As per ToR the following aspects are required for this study:

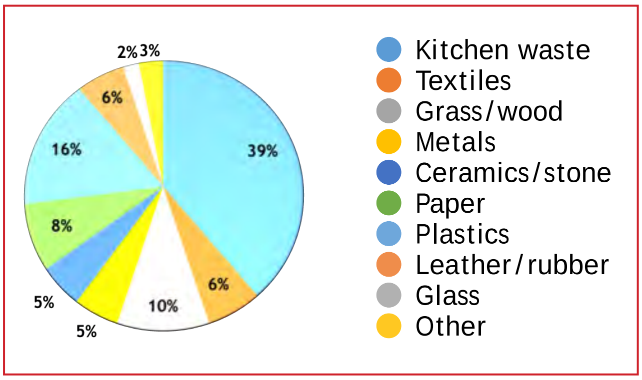

Figure 2. Average waste composition Dar es Salaam

- A preliminary lay-out of the installations
- A concise description of the necessary investments
- A concise description of the needed site and facilities
- A concise description of all needed operations
- Calculation of the number of employees needed for all operations, including job opportunities for waste pickers and needed training
- Calculation of CAPEX and OPEX including financial feasibility
- Qualitative description of the environmental aspects
- Planning until realisation
- Planning of stakeholder engagement (e.g. DCC, or the future Dar Waste Authorities)

3. Description of installations, operations and facilities

3.1 General description

The incoming municipal waste at Pugu can be processed by using an installation comprising a magnet, drum sieve, sorting lines and a composting field, as schematically presented in Figure 3 below.

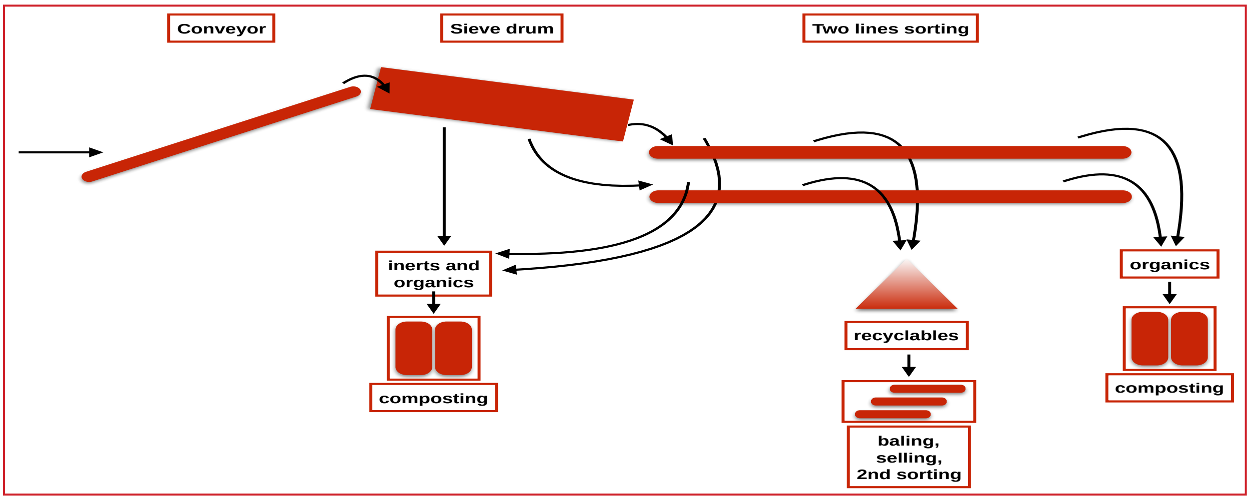

Figure 3. Schematical set up of sieving and sorting installations

The installation will yield a substantial volume reduction of the waste to be dumped. Most of this will be done by removing the organic and inert fractions and leading them through a composting/stabilisation field where employees can be put to work in turning the windrows. The resulting compost cannot be used in agriculture due to its expected poor quality, but it can be used in daily and final coverage where it will reduce the need for using soil and aggregates. The resulting plastics and paper can be sold for recycling or prepared for use as alternative fuel in the cement industry.

3.2 Lay out and description of the separation and sorting facility and processes

The drawings below (Figures 4 and 5) present a top and side view of the needed mechanical separation and manual sorting facility.

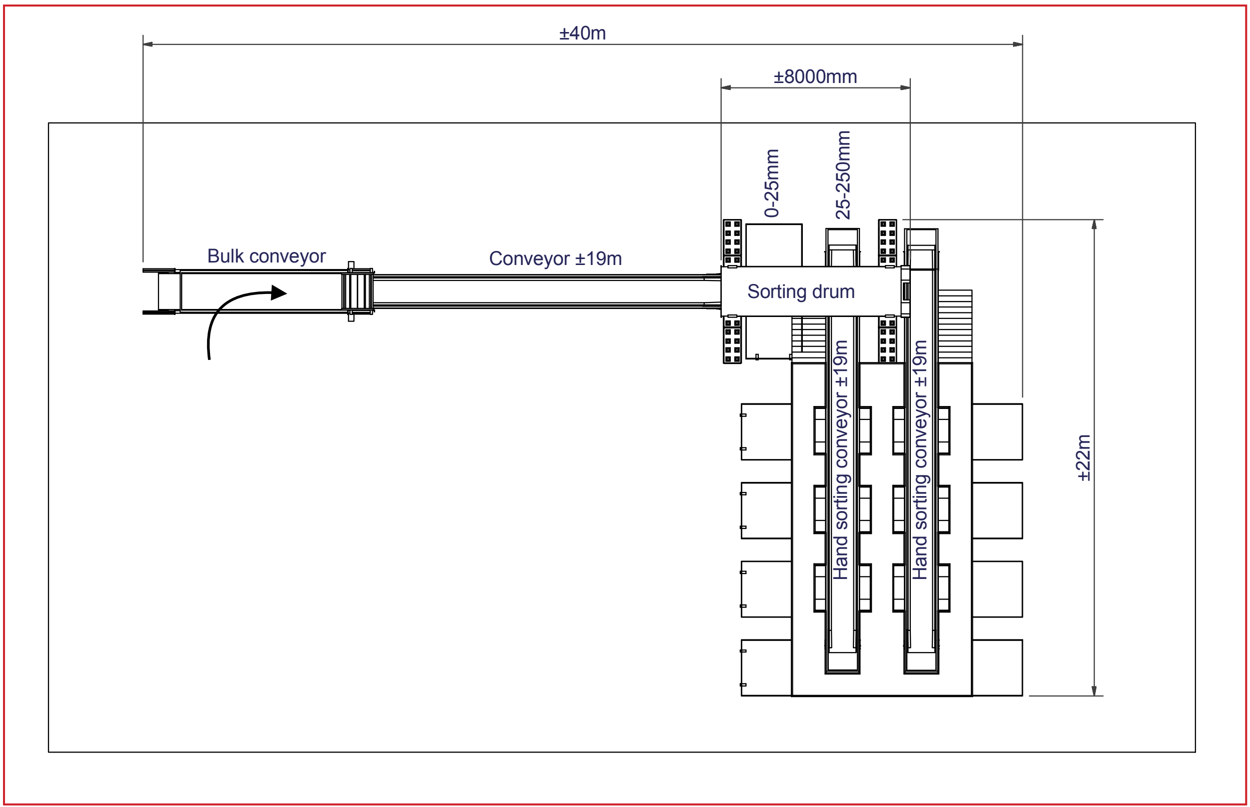

Figure 4. Top view of mechanical and manual separation facility

The installation will be installed on a flat level concrete floor. It is built up by combining separate components that have proven to be able to handle this type of waste. The process will be continuous so all components will be designed to have a capacity needed for continuous, connected operations.

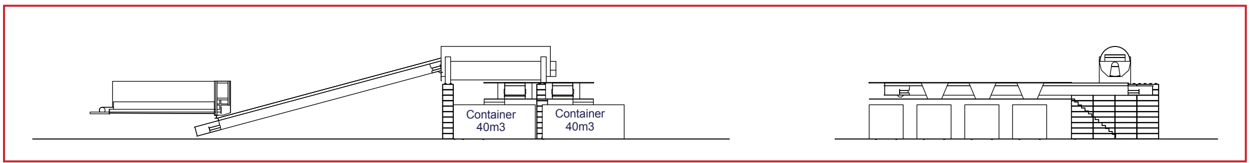

Figure 5. Side view of mechanical and manual separation facility

The installation consists of a hopper, able to accommodate dosing by a crane or shovel. No shredding will be needed as long as the waste is solely from household origin and not collected in plastic bags. Magnet and manual separation of metals is anticipated although it may be expected that metal-contents will be very low.

The hopper will be supplied with a bulk conveyor, dosing the waste on a conveyor belt leading the waste up into a rotary sieve drum. The magnet will be placed above this belt.The sieve will separate the waste into three fractions. The finest one (mesh 0-25 mm) will fall into a bunker or 40 m^3 container. This fine fraction, consisting mainly of fine organics and inerts (glass, sand) will be transported to the composting field. The middle (mesh 25-250 mm) and coarse (>250 mm) fraction will be dosed on two conveyor belts with sorting tables providing adequate workplaces for the sorting team (30-40 employees). Two separated lines for sorting the middle and coarse fractions are needed in order to optimise the overall sorting capacity and quality.

All manual sorting is aiming at reclaiming recyclables like paper, metals and plastic bottles/foils and removing components like larger pieces of bricks, carpets and textiles, chemicals, batteries etc. that may disturb the composting activities. The products of this positive and negative sorting will be thrown into funnels that lead to 40 m^3 containers underneath the sorting platform and tables. Filled containers will be removed. Sorted out plastics/paper will be baled and stored or directly sold to interested private enterprises. The same holds for metals. Mixtures of plastics and paper may be fit for use as secondary fuel in the cement industry (Twiga and others). Post-sorting and post-treatment investments and operations are not included in the scope of this report.

The sorting facility (below in Figure 6 shown in perspective drawing) is placed under a roof providing shade for the workers. All running systems are electricity powered by using a generator with sufficient capacity. Process control will be restricted to simple on/off switching on the equipment components and additional emergency-stop switches near the sorting tables.

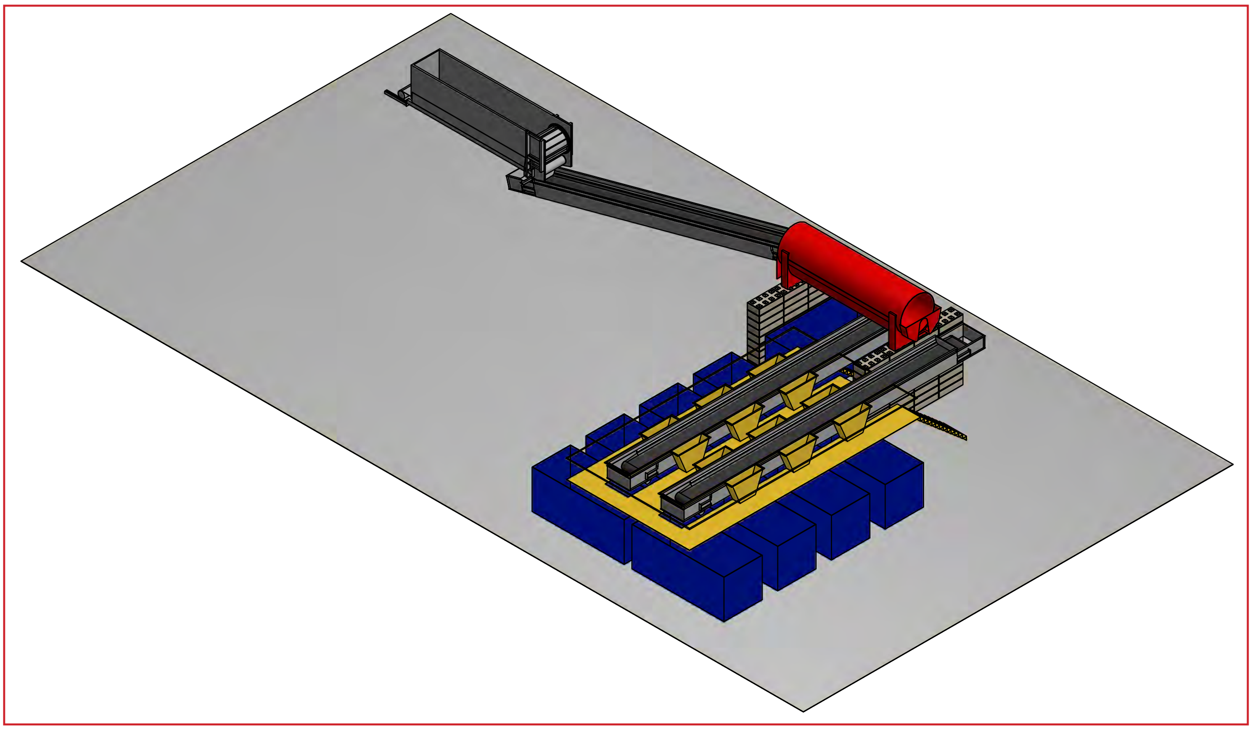

Figure 6. Perspective drawing of mechanical and manual separation facility

The relevant data on the site, the installation and the relevant cost factors are summarised in Table 1 below.

Capacity	40 tons/hr	This capacity equals 100.000 tons/yr assuming a 15-20% downtime.
Sieving diameters	0-25 mm 25-250 mm >250 mm	The lower 25 mm may have to be raised to 40 mm in case the incoming waste contains to many parts that may clog the holes in this part of the sieve.
Generator capacity	120 kW	
Concrete floor	3-4000 m^2	
Roofing sorting facility	400 m^2	
Needed mobile equipment	1 shovel 1 container truck	Shovel and truck may be shared with other landfill operations.
Needed # 40 m^3 containers	15	
Needed employees	1 chief operator/mechanic 3 shovel/truck drivers/mechanics 40 sorting and cleaning workers	Operator, drivers, mechanics able to replace each other. All workers able to work in sorting and in cleaning the sites premises.

Table 1. Relevant data

The output of the installation is expected to be as represented in Table 2:

Fraction	%	tons/year	tons/day	destination
Material for composting	60%	60.000	200	Composting/stabilisation
Paper, cardboard and plastics	17%	17.000	60	Baling, post sorting, secondary fuel production
Metals	2%	2.000	7	Recycling
Residues	21%	21.000	70	Landfill

Table 2. Output of the installation

In this scenario the sorting is aiming at maximising the recyclability of paper and plastics. The alternative scenario would be to use this fraction for producing a secondary fuel for the cement industry. In fact the Dar es Salaam branch of Heidelberg Cement, called Twiga, is seriously interested in using this fraction in their production. In that case the quality requirements of the paper/plastics fraction would be lower which would lead to a shift from residues towards the paper/plastics fraction resulting in 15% residues and 25% paper/plastics fraction.

3.3 Lay out and description of the composting/stabilisation facility and processes

The drawing in Figure 7 presents a schematic top view of the required composting activities. The organic/inert fractions produced in the sieving/sorting facility will be mixed by the shovel and will be transported to a composting field of approximately 1 ha. There it will be put on windrows of appr. 7-10 meters wide, 1 meter high and 100 meters length. Other configurations are possible too, provided the height will be no more than 1,5 meter. The rows contain the waste produced in

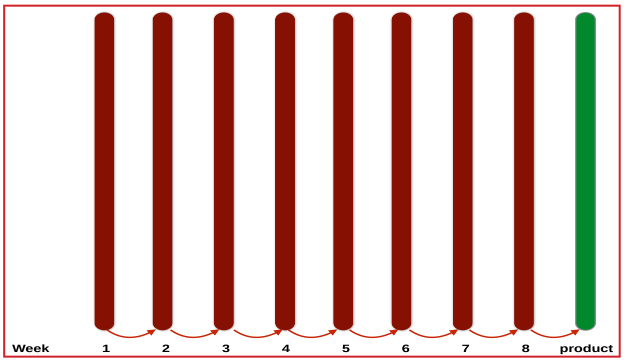

Figure 7. Schematic top view of composting activities

one week. So in the Pugu situation row 1 will contain 1000-1200 tons, equaling 800-1000 m^3. Every row will be turned by hand each week. After 8 weeks a product remains in which most of the readily degradable organics have been broken-down and most of the water has been evaporated, leaving a stable, almost inert and sandy product. The degradation and evaporation leads to a 50% m/m reduction and so produces 500 tons of product per week or 90 tons/day.

The composting can be done on a levelled part of the landfill with consolidated and/or stabilised soil. The site can however also be provided with a concrete floor making the operations much easier. This is an important choice as it will influence investments and costs. In the case of using a concrete floor there will be a need to collect the runoff water in a basin supplied with a pump to spray it back over the windrows. This enhances the composting process and enables the evaporation of excess water.

Another factor is of course labour. As an assumption, one worker could turn 5 m^3 per day and this would lead to a needed workforce of 300. Lower productions per worker will of course lead to a higher number of needed workers. On the other hand it is clear that future changes of cost of labour vs. mechanisation may lead to shifting to a more mechanised way of turning the windrows.

There will be no need for intensive management. It can be done under the surveillance of the chief operator of the sieving/sorting facility.

Picture. Outdoor windrow composting

4. Human resources

4.1 Numbers of employees

As described above the operations will need a total of some 50 employees for the sorting and sieving activities and 300 employees for the composting activities. Most of these employees may be recruited from the existing population of informal scavengers now working and living at the Pugu site which is estimated to be 300-350 persons as well.

4.2 Wages, training and occupational safety

The new facility is expected to provide proper and secure jobs to the people now having an insecure, unhealthy, dangerous and low income life at Pugu. Wages for employees in the sorting and composting activities are set on TzS 150.000 per month providing them with a, be it low, but still secure income. An informal sector worker at Pugu currently makes ca. 300.000 TzS per month on collecting recyclables. To make workers accept this change, additional social or financial measures (as for example: free housing) will need to be considered. These extra costs are not included.
Technical training will not be needed. The focus will be on introducing and maintaining daily working routines and attitudes and on social support in this important change in their lives.
All workers will be supplied with safety shoes, -gloves and -clothes, inhalation-filters and adequate disinfection, first aid and medical supplies.

5. Financials

This chapter describes and discusses the direct capex and opex and the direct overall costs. In the last paragraph of this chapter the (indirect) revenues are discussed.

5.1 Capex

The investments (and resulting depreciation) needed for the installations described above, are summarised in Table 3.

Operation	Sieving and sorting			Composting/stabilisation		
	basis	investments	depreciation/yr	basis	investments	depreciation/yr
Civil works	floor: 4.000 m² at €25 /m²	€ 100.000	€ 6.667	floor: 10.000 m² at €25/m²	€ 250.000	€ 16.667
	roofing: 400 m² at €20/m²	€ 8.000	€ 533	-	€ 0	€ 0
Installations	dosing, magnet separation, sieving, sorting, baling, generator	€ 1.000.000	€ 100.000	-	€ 0	€ 0
Mobile equipment	shovel, truck, containers	€ 250.000	€ 50.000	-	€ 0	€ 0
Transport/import	10% on installations and equipment	€ 125.000	€ 12.500	-		
Contingency	10% on all	€ 135.800	€ 13.580	10% on all	€ 25.000	€ 1.667
Total		**€ 1.618.800**	**€ 157.200**		**€ 250.000**	**€ 16.667**

Table 3. Investments and depreciation

The overall investments are estimated at € 1,6 million. They are based on ± 30% estimates and include the use of some secondhand, refurbished and conditioned parts of equipment (sieve, magnet, baling). Transport and import is included at 10%.

5.2 Opex

The operational costs are:
- maintenance at 4% of investments per year as an average for combined sieving/sorting investments
- maintenance at 2% of investments per year for composting floor
- labor expenses chief operator/mechanics at TzS 300.000 per person per month
- labor expenses drivers/mechanics at TzS 200.000 per person per month
- labor expenses sorters/composters at TzS 150.000 per person permonth
- diesel fuel costs for mobile equipment and generator are set at TzS 2.000 per liter.

The rate of Euro against the Tanzanian Shilling is set at 2.200.

Table 4 summarises the most important operational expenses.

Operation	Sieving and sorting		Composting/stabilisation		Total
	basis	costs in €/year	basis	costs in €/year	costs in €/year
Maintenance	4% of investments	€ 64.752	2% of investments	€ 5.000	€ 69.752
Chief operator	1 person	€ 1.636	-		€ 1.636
Drivers	3 persons	€ 3.273	-		€ 3.273
Sorters/composters	40 persons	€ 32.727	300	€ 245.455	€ 278.182
Fuel	300 liter/day	€ 90.000	-		€ 90.000
Total		**€ 192.388**		**€ 250.455**	**€ 442.843**

Table 4. Operational expenses

5.3 Overall costs

The table below summarises opex and capex and adds interest expenses, set at 5% per year.

Operation	Sieving and sorting	Composting/stabilisation	Total costs per year	Total costs per ton
Depreciation per year	€ 157.200	€ 16.667	**€ 173.867**	€ 1,74
Operational costs per year	€ 192.388	€ 250.455	**€ 442.843**	€ 4,43
Interest per year	€ 80.940	€ 12.500	**€ 93.440**	€ 0,93
Total costs per year	**€ 430.528**	**€ 279.621**	**€ 710.150**	€ 7,10
Total costs per ton input	€ 4,31	€ 2,80	€ 7,10	

Table 5. Total costs of operations

It turns out that total operations of sieving, sorting and composting will cost € 7,10 (TzS 15.600) per ton or € 0,71 (TzS 1.560) per household per month.

5.4 Revenues

There may be revenues coming from the produced metals and paper/plastic mixtures.
A production of 5-7 tons per day of metal scrap could represent a market value of € 300 per day, adding up to € 100.000 per year. This would lower the costs per ton to € 6,50. It must be said however that the percentage of metals in the incoming waste, the sort-ability of these metal parts from the waste and its value in the Tanzanian market are unsure and it needs further investigation. This investigation could also lead to the conclusion that it is not feasible to add magnet-removal of metals to the operations.

The resulting paper/plastic mixtures may have some value to companies that are able to further sort out these mixtures into mono-streams with higher values. The same may hold for using the mixtures in the production and use of secondary fuels for the cement industry. For this businesscase it is preferred to keep this revenue at zero.

5.5 Comparison with landfill costs

Currently the tipping fee at Pugu is 1.500 TzS per ton. This fee is extremely low and needs raising in order to make operations sustainable. The Worldbank[2] estimates the costs of Sanitary landfilling in Low Income Countries to be in between $10-30 per ton. These figures hold for newly designed and fully equipped landfills. If we assume the cost of engineered landfilling under Tanzania circumstances to be around € 10 per ton, we can conclude that the above operations for sorting and composting are at a similar level.

6. Environmental aspects

There are a number of environmental gains to be found in implementing the operations described above:

- The operations will reduce the use of needed landfill volume and surface by almost 80 % for each ton of treated household waste. A little over 20% will remain as a residue to be landfilled. The composted product (27% on input after degradation of organics and evaporation of water) will be used at the landfill to replace the use of soil for daily coverage and it will therefore not consume any landfill space or surface. Table 6 summarises the mass balance.

Mass balance					
		tons/year	tons/day	%	
Input	household waste	100.000	333	100%	
Output	Composted product	27.000	90	27%	to be used at landfill
	Paper, cardboard and plastics	17.000	57	17%	
	Metals	2.000	7	2%	
	Residues	21.000	70	21%	to be landfilled
	Total	67.000	223	67%	

Table 6. Mass balance

- As said above, the use of composted organics/inerts replaces the use of a daily input of 90 tons of sand/soil/gravel for covering incoming waste, which can be accounted for as direct prevention.
- The operations additionally contribute to the recycling of 7 tons of metals and 57 tons of paper/plastic mixtures per day.
- If the organics in the household waste would be dumped, they would produce uncontrolled emissions of CO_2 and CH_4. This last emission is especially harmful as CH_4 emissions contribute 21 times more to the greenhouse effect than CO_2. Preventing the formation and emission of this CH_4 from an uncontrolled dumpsite, through pre-treatment by controlled composting, will therefore result in a substantial reduction of the greenhouse-effect of the dumpsite. The box below provides a calculated guess of this reduction.
- The last environmental gain to be mentioned is the prevention of the uncontrolled production and emission of leachate to surface and groundwater. A calculation of the harmful effect of the emission of leachate is very difficult to make as it depends on a number of local circumstances inside and outside the landfill body.

[2] Worldbank Urban Development Series, March 2012, No. 15, “What a waste, a global review of solid waste management”

Model calculation: Greenhouse gas reduction potential of the Pugu composting strategy

When starting from 100.000 tons of household waste going to a landfill site per year, a volume of some 50.000 tons of organic fraction is built in into the landfill body. Production of biogas will start up directly and will reach its maximum within a year. After that it will continue at this maximum for 10 years and after that it will gradually decrease to zero in the next 20 years. Applying a gas collection system right from the start may capture 50% of the gas production as long as the top of the landfill is not covered. After covering capture efficiency may rise to 90%. Overall efficiency of a well organized landfill with a nearly gastight cover is estimated to be no more than 70-80%.

As 50.000 tons of organic waste will produce an estimated 10 million NM^3 (normal cubic meter) of landfill gas (with 50% CH_4 and a GHG-factor of 21) the effective emission coming from these tons in a sanitary landfill adds up to an equivalent of 20 million NM^3 of CO_2.
In a situation in which this waste is brought into an unorganised open dump, virtually all of the 10 million NM^3 of gas will be emitted resulting in an equivalent CO_2 emission of 100 million NM^3.

Box. Model calculation of Greenhouse gas reduction potential

7. Planning

A possible planning for the design and implementation of the investments and operations is provided below.

- Additional investigation of the composition of the waste: 2 months
- Definitive design: 1 month
- Procurement: 2 months
- Transport, import and installation: 5 months

All civil constructions can be done parallel to this planning. It is assumed that permitting can be done parallel too. Under these assumption the whole process of design, procurement and construction would need 10 months until the start of operations.

8. Stakeholder engagement

It could be difficult to assign the responsibility for these investments and operations. Of course the Pugu site is the responsibility of the Dar es Salaam City Council, but on the other hand the waste is in the hands of the Municipalities. In order to (i) prevent a situation of competition and uncertainty and (ii) to ensure the best circumstances for achieving progress and optimisations, it is advisable to bring the new activity under the responsibility of the Dar es Salaam Solid Waste Management Authority as proposed by the Dutch 2016 Expert Mission.

9. Other aspects

The new activity at Pugu can be seen as proven and commercial scale. At the same time it can be presented as a showcase, demonstrating the possibilities of this approach. Pugu is a good place to start but there is no reason not to start and copy the concept (or at least the sieving/sorting part of it) at other places, for example at Transfer Stations that are anticipated to be planned in Dar.

The capacities used in this report are only used for a model calculation of costs and impacts. Increasing this capacity may lead to lower costs per ton as there will quite some economy of scale in investments and operations.

The sieving and sorting facility is powered by electricity from a diesel powered generator. It may be worth considering PV/batteries operations to replace this generator.

The composting part of the new activity may also be of importance for composting market waste. As market waste will be less contaminated than the sieved-off organic fraction of household waste, it is wise to perform the composting of market waste on separate windrows in order to produce a marketable compost for use in agriculture.

10. Conclusions

In this report the installations and operations for a combined sieving/sorting/composting plant at the Pugu dumpsite in Dar es Salaam are presented. The resulting costs, mass balances and environmental impacts are summarised below:

- A total investment of € 1,6 million is expected.
- Overall costs are estimated to be € 7,10 (TzS 15.600) per ton or € 0,71 (TzS 1.560) per household per month. These costs will be at the same level as the costs of sanitary landfilling.
- A total workforce of 350 employees is needed; equaling the population of informal workers, currently active at the Pugu dumpsite.
- Some 20% of the input will remain as residu to be landfilled.
- Some 20% of the input will be sorted out as recyclable metals and paper/plastic mixtures.
- Model calculations provide an estimate of the reduction of yearly CO_2 emissions reaching an equivalent of 20-100 million NM^3.
- The whole process of design, procurement and construction would need 10 months until the start of operations