Report on Immediate Upgrades for The Pugu Kinyamwezi Landfill and Planning for Construction of Sanitary Landfills in Dar Es Salaam, Tanzania

May 2017

This report is a deliverable of Activity 4.1.5. of the CCAC Work Plan project for Dar es Salaam, implemented by the International Solid Waste Association on behalf of the Climate and Clean Air Coalition (CCAC) Municipal Solid Waste Initiative (MSWI)
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Introduction

The International Solid Waste Association (ISWA) is working with the city of Dar es Salaam, Tanzania under the city funding programme of the Climate and Clean Air Coalition (CCAC) Municipal Solid Waste Initiative (MSWI). The Phase 1 scoping missions started in December 2014 and was concluded with an Action Plan in April 2015, focusing on improving the status of solid waste management in the city of Dar es Salaam.

Following this period, ISWA received Phase 2 funding to assist the city to conduct Work Plans for various areas in solid waste management, based on the city’s priorities previously outlined in the Action Plan. The Phase 2 period started in September 2015 with a kick-off meeting gathering the most relevant local stakeholders on the ground in order to allow for a better planning for the projects to be completed. Additionally, ISWA invited representatives of the National Environment Management Council (NEMC), to ensure support on the country level, and visited the local UNEP office to learn and discuss about opportunities to align the Work Plan activities with other on-going and potentially relevant projects in Dar. The Work Plan was prepared with the input of the Dar local authorities (the Dar City Council (DCC) and the Local Government Authorities (LGAs) of three Municipalities, Ilala, Kinondoni and Temeke), ISWA experts and other important stakeholders (such as BORDA, the Bremen Overseas Research and Development Association and Nipe Fagio, a local NGO).

After the kick-off meeting in September 2015 the continuation of the implementation period was deferred, due to local elections and changes on the national and city level. By the time ISWA’s work could be resumed in August 2016, substantial changes have been made in the city’s administrative divisions; two additional municipalities (Ubungo and Kigamboni) were in the process of being established in addition to the existing three (Kinondoni, Ilala and Temeke).

In August 2016, ISWA has conducted a 2.5-day capacity building event which focused on potential upgrades of operations at the Pugu Kinyamwezi dumpsite and on basic principles for the construction of sanitary landfills. The capacity building was held by two experts, Dr Sahadat Hossain, professor of the University of Texas in Arlington and David Dugger landfill manager of the City of Denton. The event was attended by 19 stakeholders from all sectors, including the local authorities, academia, NGOs and private companies.

This document aims to provide an overview on the most important considerations at the construction of a sanitary landfill. The report is based on the content of the capacity building provided in August 2016 and on other documents written by ISWA experts and published by ISWA, such as the:

- Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country ¹
- A Roadmap for closing Waste Dumpsites, The World’s most Polluted Places ²
- International Guidelines for Sustainable Landfill Evaluation ³ (available in ANNEX I.) and

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¹ Munavar, Edi; Fellner, Johann; “Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country”, Austria, International Solid Waste Association (ISWA), 2013


Presentations of the ISWA World Congress 2013 sessions, held in Vienna, Austria. The above documents are also available on the ISWA Knowledge Base.

Moreover, other literature was resourced, including the report on the Dutch “Expert Mission on Integrated Solid Waste Management (ISWM) to Dar es Salaam” and technical reports prepared by Eng. Alexander Fecher, who is a Solid Waste Management & Partnership Advisor in the Dar City Council, since early 2015.

A trip report of the capacity building event in Dar es Salaam, a visit to Addis Ababa and relevant meetings in both cities during 6-13 August 2016 has been included in the final chapter (Workshop on Landfill management - Trip Report. August 2016) of this report.

In September 2016, a Dutch delegation consisting of three solid waste management experts conducted a mission to Dar es Salaam, on behalf of the Ministry of Environment of the Kingdom of the Netherlands and in cooperation with the Royal Dutch Embassy in Tanzania. The expert mission report is an exhaustive and the most up to date description of the solid waste management situation in Dar es Salaam. Based on the report findings, the Netherlands has continued to work with the city and is hoping to soon establish a Metropolitan Waste Management Authority and provide grant funding for feasibility studies to improve the waste management system in Dar es Salaam. If the first phase of the project proves to be a success, the Netherlands will unlock large scale funding for implementation. To support this process already within the CCAC Work Plan project framework, ISWA commissioned one of the members of the Dutch delegation to complete a technical report on how to improve separation and recycling at the Pugu dumpsite (the report is available in ANNEX III.) This deliverable and the recent positive developments with the Dutch delegation working in Dar es Salaam, may also be helpful to the City to achieve some of the goals discussed during the CCAC Work Plan project capacity building events, in example the construction of transfer stations.

Based on the results of the CCAC Work Plan capacity building event on landfilling, the findings of the Dutch expert mission and other sources, the current capacity at the Pugu landfill does not validate the need for a new landfill within the next 10-15 years. However, since this issue is raised among local government authorities on a regular basis ISWA saw the need to create this reference document which discusses technical requirements for the planning and construction of an environmental friendly and technically sufficient final storage for the municipal solid waste of Dar es Salaam. This document should prevent the execution of initiatives to establishing another landfill in the city without utilizing of the existing capacity at Pugu landfill at first.

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5 ISWA received permission from the authors to publish the document on the ISWA Knowledge Base.
6 This position is sponsored by German Development Cooperation; Gesellschaft fuer International Zusammenarbeit, (GIZ)
Solid Waste Management Situation in Dar es Salaam

Although Dar es Salaam is not the official capital of Tanzania, it is the largest and the most influential city in terms of business and economy. The city has a total area of 1,393 km² and a population of 4,364,541 living in five municipalities, Ilala, Kigamboni, Kindondoni, Temeke and Ubungu. Dar es Salaam is the third fastest growing city in Africa and the ninth fastest in the world. The urban population is expected to reach approximately 10 million by the year 2030. 70 % of the city residents are currently living in unplanned settlements, which – together with the rapid expansion and urbanization – will pose an increased demand on urban services, including waste management. As a result of the population and economic growth during the past decades the amount of waste generated has also increased significantly.

The waste generation in Dar es Salaam has been tripled during the past 16 years; the city generates 4,252 tonnes of MSW per day, with a per capita waste generation of 356 kg/year/person. The amount of waste generated per municipality and in total is shown in Table 1. below:

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Wastes generated per day (tonnes)</th>
<th>Waste generated per year (tonnes)</th>
<th>Waste generated per capita (kg/year)</th>
<th>The average amount of wastes collected per day</th>
<th>% collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilala</td>
<td>1,088</td>
<td>397,120</td>
<td>325</td>
<td>600</td>
<td>55</td>
</tr>
<tr>
<td>Kinondoni</td>
<td>2,026</td>
<td>739,490</td>
<td>417</td>
<td>1,030</td>
<td>51</td>
</tr>
<tr>
<td>Temeke</td>
<td>1,138</td>
<td>415,370</td>
<td>303</td>
<td>398</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>4,252</strong></td>
<td><strong>1,551,980</strong></td>
<td><strong>356</strong></td>
<td><strong>2,176</strong></td>
<td><strong>51</strong></td>
</tr>
</tbody>
</table>

Table 1 Waste generation in three municipalities of Dar es Salaam

Waste collection coverage is 51 %\(^8\) of the generated municipal solid waste. Collection service schedules are rarely inconsistent due to traffic congestions and under planning. The remaining fraction of the generated waste is not formally collected; it is buried, burned, or illegally dumped. Primary collection is often outsourced to the private sector or community based organizations (CBOs) and is managed with the contractor’s own vehicles or push carts, depending on the infrastructure of a specific area. Private contractors usually transport the waste directly to Pugu Kinyamwezi dumpsite (20-30 km), but CBOs, are not equipped to travel longer than a few kilometers. There are no official transfer stations only – many times informal - collection points, where secondary collection takes place, accomplished by the private sector or the municipalities who have a limited vehicle feet.

The main portion of municipal budgets allocated for solid waste management is spent on the collection and transportation of waste.

Waste collected through the formal scheme is delivered to the Pugu Kinyamwezi dumpsite located ca. 30 km from the city. The site was initially planned to be a sanitary landfill, however the plans failed at the construction stage when funds proved to be limited. The site is now operated as an open dump with no liner, no soil cover

\(^7\) The city recently added two municipalities, Kigamboni and Ubungu, to the existing three. There was no data available from waste generation of the new municipal districts at the time of writing the report.

\(^8\) Estimate based on numbers presented by the municipalities. Other reports, such as the Expert Mission report of the Dutch delegation estimate this number to be much lower, around 30 %.
and no leachate treatment. The DCC receives gate fees in exchange of waste transported to Pugu. The fees (1500 TZS/t) are paid mostly only by the private contractors since the municipalities are paying on an occasional basis only.

There are limited formal recycling activities in the city, recycling is mainly done by the informal sector. Approximately 420 people work at the Pugu dumpsite unofficially and there is no data available on the rest of the informal waste pickers within the city.

One of the main challenge is to improve current landfilling practices at Pugu and establish new transfer stations within the city in order to make waste shipments shorter. As per law, the Dar City Council is responsible to operate the Pugu dumpsite and it is the only authority permitted to build new (sanitary) landfills. However, building new landfills requires appropriate land, substantial financial investment and an increased internal capacity for proper management and operation.

Overall remediation and improving current operations at the Pugu dumpsite is planned to be implemented through funding raised by the Dutch delegation. Additionally, a report on potential upgrade to the Pugu dumpsite was written by Hans Breukelman, consultant to the Dutch Ministry of Environment. The report is part of the deliverables of the CCAC Work Plan project for Dar es Salaam and discusses a potential deployment of a large-scale sorting facility at the dumpsite. The plant would also sort organic waste and thus produce low quality compost which could be used as an alternative cover material for the dumpsite.
Recommendations to upgrade current operations at the Pugu Kinyamwezi Dumpsite

Current situation at the Pugu dumpsite

The Pugu dumpsite is located approximately 30 km from the city in Temeke municipality. The infrastructure leading to the dumpsite is rather basic, there are no concrete access roads, only not well maintained dirt roads leading up to the dumpsite. In rainy season, it can be very difficult to approach the dump and often it is also impossible to access it for the waste haulers. Since Tanzania is a tropical country with two rainy seasons (a shorter and a longer season in November-December and in March-May respectively) this can mean that sometimes proper waste disposal needs to be stopped for longer periods (e.g. weeks). Operating the equipment on an instable dump is dangerous and can lead to accidents such as the one on Figure 1 where an excavator was fallen to the water.

The Pugu dumpsite is not fenced and therefore it is freely accessible to informal waste pickers searching for recyclables. The site is operated as an open dump, without a designated working face and waste is dumped all over the surface of the area. No leachate treatment exists at the site.
In 2016, the Dar es Salaam city council constructed another landfill within the dump area. The landfill area is approximately 800-1000 m², it has concrete walls and basement and leachate pipes underneath the concrete base layer. A smaller size leachate pond is to be found next to the site. The landfill is currently not in use; however, it is estimated to be able to contain a limited amount of waste (ca. one year of the waste disposed in Dar es Salaam, accounting for a 4000 tonnes/day waste generation and maximum 50 % collection coverage). It is not entirely clear how the city intends to use the new landfill.

![Image of new landfill and leachate treatment pond](image)

Figure 2. The new landfill built on the area of the Pugu dumpsite (left) and the leachate treatment pond (right)

Pests, odor and human settlements in close proximity of the Pugu dumpsite create a high risk for vector borne diseases and other permanent health hazards. Additionally, there is constant exposure of odor and noise pollution affecting the Pugu neighborhood.

Previous recommendations to upgrade Pugu

The first recommendations to upgrade the Pugu dumpsite were provided by a World Bank commissioned technical report in 2013⁹. The report provides capital expenses (CAPEX) and operational expenses (OPEX) schedules and identifies the upgrade of the dumpsite as a high priority activity of stage 1 measures. The author also provides recommendations to establish a sanitary landfill at Pugu in the stage 2 development process.

In the following sections, the recommendation of the ISWA experts (Dr. Sahadat Hossain and David Dugger) and the recommendations of the Ministry of Environment of the Kingdom of the Netherlands will be introduced.

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ISWA recommendations to upgrade the Pugu dumpsite

During the workshop, participants conducted a trip to the dumpsite and discussed the current situation, including potential actions to improve actual operations at Pugu. Dr. Sahadat Hossain and David Dugger, the two ISWA experts agreed to the findings of other reports:

- Although waste is spread out all over the site and the compaction density is very low, Pugu has sufficient capacity to be the final disposal option for the waste generated in Dar es Salaam for the next 5 to 10 years.

- The dumpsite area should be fenced or isolated from its environment in another way. Fencing will also prevent the informal sector to enter the dumpsite and provide an opportunity to the Dar City Council to take ownership of the waste at the dump and thus regulate waste pickers’ activities. It is important to mention that in order to succeed with the formalization of the informal sector worker, additional social and economic measures, such as regular public consultations, agreements about workers’ wages, etc. are of crucial importance.

- Access roads: Crowning the access roads would be necessary before the next rainy season. This would reduce the number of accidents and enable better waste disposal throughout the year. Roads should be kept clean in order to ease the traffic situation.

- A working face area need to be designated to make dumping more manageable. Truck drivers could receive training on how to dump the waste and a loop could be established at the working face to allow for easier traffic, better accessibility, etc.

- Machines should rotate on the working face area to ensure a better compaction. The proposed compaction density for waste with this moisture content would be approximately 600 kg/m³, however this depends from the weight of the machine, slope steepness and other factors.

- There is only limited equipment available at the dumpsite, purchase of new or used machines can be planned and thus gradual improvements are possible.

- An alternative daily cover could be the organic waste fraction composted with a low cost, low technology method, such as windrow composting. Soil cover would also be possible. Tarps could be helpful to prevent pests and birds to access the working face and the dispersion of waste. Tarps could last for 1-1.5 years; however, they might not be an economically feasible solution under the current operations.

- Waste at the dumpsite could be condensed and thus a liner could be put in the bottom of the landfill to ensure that pollution emission is stopped. Cells could be formed and waste disposal can be planned on a more controlled way.

- Training could be provided to waste workers, service providers who deliver waste to Pugu with their own trucks and to Dar es Salaam City Council staff.

- Runoff and leachate could be separated and treated on-site with basic methods.

- On the economic side, a separate budget should be considered for the operation of the dumpsite. Furthermore, waste tipping fee payments must be enforced to recover operation costs.
Study of establishing a sorting facility at the Pugu dumpsite – Bread BV

After the Netherlands sent an expert mission to Dar es Salaam in September 2016, ISWA saw a high potential for the Dutch Delegation to continue working with the city towards improvement of solid waste management services and facilities. The initial assessment report 10 of the Dutch Delegation and the presentation introduced to the Dar es Salaam City Council and other stakeholders during the Final Conference of the CCAC Work Plan project on 27 April 2017 includes detailed planning to upgrade the Pugu landfill within the next 3-4 years, if pre-requisites (such as the establishment of a Metropolitan Waste Management Authority in Dar es Salaam) will be fulfilled.

As a next step to the Pugu dumpsite upgrade, funding could be leveraged to build a large-scale sorting and composting facility for MSW at the dumpsite. Therefore, ISWA commissioned Mr. Hans Breukelman (BreAd B.V.), consultant to the Environmental Ministry of the Netherlands to write a technical report on upgrading the Pugu dumpsite, specifically focusing on the feasibility of a Material Recovery Facility (MRF).

The objective of the report (“Separation, sorting and composting of municipal solid waste at the Pugu dumpsite in Dar es Salaam”) was to explore the potential benefits of 1) an installation for separation and sorting of recyclables and 2/ development of a composting facility for household waste at Pugu landfill in Dar es Salaam, Tanzania. The target amount of MSW to be processed with such installation was tentatively set to a minimum of 100,000 tons/year.

The study was delivered as a separate report to the CCAC Municipal Solid Waste Initiative and the Dar es Salaam City Council (the report is also included in ANNEX III. of this document). The report includes a preliminary layout of the installations, description of the necessary investments, the required site and facilities, the necessary operations to run the site, calculation of the number of employees needed for all operations, and the description of job opportunities and required training for the informal sector. Moreover, an estimate of capital expenses (CAPEX) and operational expenses (OPEX) and an overall financial feasibility is described.

Outcomes of the CCAC City Exchange to Durban implemented in January 2017

On behalf of the CCAC, ISWA facilitated a city exchange between Durban, South Africa and three African cities (Nairobi and Muranga, Kenya and Dar es Salaam, Tanzania) on 16-19 January 2017. The aim of the trip was to help the cities to plan and undertake actions related to waste disposal to mitigate the emissions of short-lived climate pollutants from landfilling and other areas of solid waste management.

The city exchange focused on best practices in landfill site management as part of comprehensive efforts to reduce short-lived climate pollutant (SLCPs) emissions in the municipal solid waste (MSW) sector in Kenya. This approach is defined in the CCAC MSW Initiative to reduce methane and black carbon across the MSW sector by

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securing country commitments to undertake a variety of capacity building activities and apply best practices in policy and strategic planning for solid waste management.

Since Dar es Salaam had local government elections recently (October 2015), inclusion of two of the city officials was extremely beneficial to build more internal capacity for solid waste management.

Durban has extensive experience in developing successful and sustainable sanitary landfills through World Bank and other funding mechanisms, such as Clean Development Mechanism (CDM). Therefore, Durban could offer useful recommendations and best practices to ensure development of a suitable and sustainable sanitary landfill site(s), transfer stations and potential upgrading measures of the Pugu dumpsite. Durban also provided guidance on the best management practices of landfill operations and maintenance. The trip report of the City Exchange between Durban, Nairobi and Dar es Salaam and Durban’s recommendations on upgrading an open dumpsite are available on the Knowledge Platform\textsuperscript{11} of the Waste Initiative of CCAC and the ISWA Knowledge Base\textsuperscript{12}.

\textsuperscript{11} \url{http://www.waste.ccacoalition.org/}
\textsuperscript{12} \url{http://www.iswa.org/media/publications/knowledge-base/}
Landfill construction considerations

The purpose of landfilling is to provide a place for final storage of waste, without harming human health and the environment. After pre-treatment, the waste needs to be disposed at a site where it is isolated so that it cannot emit pollution to the environment through emissions to the air, water or soil.

Sanitary Landfills are sites where solid wastes are disposed on land without creating nuisances or hazards to human health and the environment. As Figure 3 presents, modern landfills are well-engineered facilities for waste disposal that are located, designed, operated, and monitored to ensure compliance with local and national regulations in a certain country.

Landfill site selection

The selection of a landfill site brings several complex issues that need to be considered. Landfill siting must happen with a strict methodology and on a scientific basis to prevent pollution to air, water and soil and to establish a sustainable waste management system. The use of decision support tools able to consider multiple criteria (e.g. GIS) and continuous involvement of a variety of affected stakeholders is highly necessary. During the selection for a suitable landfill site, there are main factors to be considered, such as geographical and geological features, hydrogeological considerations, capacity requirements, acquisition of land, social and socio-economic considerations and economic factors. These are explained in detail below.

Geographical and geological features

Geographical and geological considerations should include but are not necessary limited to:

- The hauling distance to the landfill from the collection points or the transfer stations (however, currently there is no transfer station in Dar es Salaam)
- Existing infrastructure, e.g. access roads to the potential landfill site
- Distance from airports, national parks, seismic zones, fault areas and other unstable areas
- Distance from human settlements
- Topography of the area

A minimum buffer zone should be considered to separate the landfill from residential dwellings and other geographically or (hydro)geologically unsuitable areas. The buffer zone aims to prevent the access to the restricted area and the potential spreading of vector borne diseases and reduce odor and noise pollution of waste management operations.

![Figure 4. Landfills nearby airport could pose a high risk for accidents due to birds](image)

**Hydrogeological considerations**

Distance from flood plains, wetlands and water bodies needs to be considered, to exclude risk of pollution to ground or surface water. Therefore, groundwater flow monitoring and the hydraulic conductivity of the subsurface layers needs to be known. Impermeable layers (e.g. clay), low conductivity and a geologically stable area far from water bodies and no risk of flooding would be an ideal site in Dar es Salaam.

**Climatologic considerations**

Specifically, in the case of Dar es Salaam it is important to consider climate data. Tanzania is a tropical country with two rainy seasons and thus the waste disposed at the landfill is more likely to have a high moisture content and therefore a high leachate generation can be expected.

**Capacity requirements**

The capacity of a landfill should be determined by the existing or planned waste management system of the city and the size of the population the site is intended to serve. In order to obtain sufficient and accurate calculations, waste streams (waste quantity) and waste composition need to be analyzed and accounted for. Moreover, the landfilling technology (compaction density, etc.), the bulk density of the waste, the landfill depth and planned slope height need to be considered.
Acquisition of land

Land acquisition could be a problem in such a densely populated city as Dar es Salaam. This aspect should be even more important when the proposed site is within the city limits or close to residential dwellings.

According to the latest information from Dar es Salaam, the city has recently allocated funding to buy land for solid waste management purposes. Alexander Fecher, Solid Waste Management & Partnership Advisor at the Dar es Salaam City Council has prepared a draft terms of reference document for site selection for waste disposal facilities. Although the document was submitted to the DCC leadership and is currently not available to the public, it can be a good basis for future site selections.

Social and socio-economic considerations

A sufficient level of stakeholder involvement is another essential element of landfill siting. Apart from the responsible government bodies and the potentially involved private sector, also the general public needs to be consulted and involved into the decision making. If this aspect is neglected, serious political difficulties can arise and prevent construction and/or operation of a landfill, such as it is the case in Addis Ababa.

Socio-economic considerations are involvement of the informal sector, cultural patterns of inhabitants of the area, or the proximity of archeological and historical sites.

Economic factors

Economic factors can be the proximity of highways and main roads, compatibility with existing solid waste management systems, cost of services, e.g. police, fire and road maintenance, development, operation and maintenance cost at the specific site, effect on property value, land development considerations or the alternative use of the selected area (e.g. highly productive agricultural use).

Other aspects to be considered are the final use of the site and political factors, such as land or waste management legislation and regulation, design and monitoring standards. In Dar es Salaam, the operation phase of a new landfill will be a crucial consideration, since funds and internal capacity in the local government are currently limited. If the construction and/or operation of a future landfill is contracted to a third party, it must be ensured that both the landfill design and operation happens in a sustainable way and in cooperation with waste management authorities of the city and the wider public.

During the siting process, authorities will need to:

1) Define the project and its exact needs,
2) Identify major environmental factors,
3) Identify candidate sites
4) Collect and analyze environmental, economic and socio-economic data

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13 Based on discussions with DCC representatives during ISWA’s final mission in Dar es Salaam during 24-29 April.
5) Evaluate and compare candidate sites
6) Screen candidate sites to a smaller (manageable) number
7) Collect and assess site specific engineering and environmental data
8) Recommend one or more sites for final selection
9) Determine final location.

The Greenfield Matrix, as shown in ANNEX II, can support decisions related to landfill site selection.

Landfill Design

The components of a sanitary landfill disposal, with landfill gas (LFG) utilization are:

- Determination of the volume or area of the landfill
- Bottom and Lateral Side Liner System
- Mechanical Stability
- Leachate Collection and Removal System
- Gas Collection and Control System
- Final Cover System and Landfill Aftercare
- Further infrastructure and facilities at the landfill site
- Operation and monitoring

Each of the components is explained in more detail below.

A landfilling method should be selected based on the selected landfill site criteria.

The key principle for landfill design is that the waste should be disposed at the safest way to the lowest cost.

Main factors to consider at the landfill design could be soil excavation, soil storage, required slope stability, groundwater and erosion control related questions.

**Determination of the volume or area of the landfill**

The volume of the desired landfill and the area of the landfill site need to be calculated. The volume of the disposed waste will be a function of solid waste generation (after deducting waste amounts for recycling), uncompacted soil density, volume reduction over time and the cover soil ratio. The required area calculation includes the landfill area (m² or acres), depth of the landfill, volume of the generated waste and number of people generating waste which is transferred to the landfill. The calculations are available in the presentation at the workshop during 11 August 2016\(^\text{15}\).

The cell type must be determined and the cell depth, width, length and configuration decided. Moreover, the applied or potentially planned capping system has to be defined.

**Bottom and Lateral Side Liner System**

The liner system should restrain contaminants from spreading, reduce the groundwater contamination and the migration of the generated landfill gas. If the subsurface layer of the selected site is already characterized by low permeability, a base sealing might not be necessary. With slightly lower permeability, compaction of the top layers with heavy equipment can be a solution\(^\text{16}\). Such actions can significantly reduce the cost of landfill construction.

![Figure 5. Landfill bottom liner construction - compacted clay liner (source: Waste Wise with ISWA)](image)

However, in case man-made liners are used, clay liners are the easiest and most cost effective to install and this material is readily available in most cases. A clay liner should be approximately 60 cm thick, compacted in 15 cm lifts and have a lower permeability than \(10^{-6}\) cm/sec. The slope of the base liner should be designed with a minimum slope of 2-3 %. A single base liner of compacted clay can be the suitable solution for the city of Dar es Salaam, as composite liners are significantly more expensive and current regulation do not yet enforce the use of them.

**Mechanical stability**

Stability of the slopes will depend on several factors, such as the design of the slopes, the waste characteristics (e.g.: density, moisture content), compression of waste and other aspects of landfill operation. Side slopes generally should have a horizontal to vertical ratio lower than 2.5:1, otherwise, there is a risk of erosion and therefore a loss of the soil cover. In poor soils (such as the sandy soil at the Pugu dump in Dar es Salaam) 5:1 slopes could be required. Also in case of extremely large landfills (height more than 30 m), the maximum slope angle should be reduced. Alternatively, installing a benching is recommended (see Figure 6).

\(^{16}\) Munavar, Edi; Fellner, Johann; “Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country”, Austria, International Solid Waste Association (ISWA), 2013
Figure 6. Landfill slope and landfill slope with benching

It is very important that suitable soil cover is put on the landfill (including the sides), as the lack of it would allow air to react with the generated landfill gas. This can lead to landfill fires, cavities within the compacted waste and therefore eventually to landfill slides\textsuperscript{17}.

**Leachate Collection and Removal System**

The baseline system needs to be covered by a layer of coarse material (e.g. coarse rock or gravel), which is the base of the leachate collection system. At local low points, perforated leachate pipes need to be installed to collect the leachate generated by the disposed solid waste. The depth of leachate collection system should be at minimum 50 cm with a hydraulic conductivity above $10^{-3} \text{ m/s}$ and a base slope of at least 2 % \textsuperscript{18}. The perforation holes need to be so small that no stones or dirt can enter in the system through them. In case of Dar es Salaam, if the liner system is a compacted clay liner, the leachate collection pipes need to be placed at relatively close intervals to maximize the leachate capture performance. Since Tanzania is a tropical country, sufficient drainage capacity needs to be designed to a landfill to avoid serious problems (e.g. landfill slides) in the rainy seasons.

A protective layer of 30-50 cm needs to be placed above the drainage layer, if possible. This layer can be of geotextile, which prevents small grained particles to migrate into the gravel and clog the drainage system\textsuperscript{19}.

A schematic diagram of the “saw-tooth” configurated leachate system (adapted from Qian et al, 2002) is shown on Figure 7. In this method, landfill cells are divided into several working faces and each of them has its primary collection pipe.


\textsuperscript{18} Munavar, Edi; Fellner, Johann; “Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country”, Austria, International Solid Waste Association (ISWA), 2013
Figure 7. Leachate management system

All landfill cells should be designed in a way, that minimum leachate is generated and should have a separate leachate collection system.

The leachate generation is a function of several factors, such as climate (including precipitation, evapotranspiration, etc.), topography, vegetation on and around the landfill, waste characteristics and landfill cover. Leachate production needs to be estimated in order to have a precise design for the collection system. The generated leachate needs to be evaluated on a regular basis and removed for treatment, disposal or recirculation. Leachate treatment can happen on- or off site. In developing countries, biological and/or chemical treatment in subsequent leachate ponds (lagoons) is the most typical. It is desirable to maximize the evaporation rate, recirculate or store the effluent leachate or discharge it to the sewage system if the contamination levels are below the permitted norms\(^20\). This multi-stage treatment is rather inexpensive; however, its efficiency is also limited.

In the operation phase, regular leachate quality analyses and leachate leakage monitoring as well as settlement and groundwater monitoring is critical in order to prevent pollution.

**Gas Collection and Monitoring System**

Landfill gas is generated by the degradation of the organic matter content of the disposed solid waste. Landfill gas contains a mixture of several gases (such as nitrogen, oxygen, ammonia, hydrogen, sulfides and volatile organic compounds, etc.); however, by volume landfill gas typically contains 45-60 % methane and 40-60 % carbon dioxide\(^21\). Landfills are the single largest man-made methane emitter sources. Methane poses a risk not only through its high reaction potential with ambient air, which could lead to explosions on the landfill, but also through its greenhouse gas (GHG) potential.


In tropical climates, the degradation rate and thus methane and carbon dioxide production is higher. However, the gas generation rate depends on several other factors, such as the age of the disposed waste, waste composition, presence of oxygen, pH, temperature, etc. It is not possible to easily influence these factors.

Landfill gas generation needs to be modeled in the design stage of the gas collection and control system to determine its size of the gas, and calculate the GHG emission reductions\textsuperscript{22}. It is important to differentiate gas production and modelling and to account only for the landfill gas which can be captured (gas recovery is typically considered 75% of generation).

The generated landfill gas follows the path of the least resistance within the waste pile. The gas will collect under solid structures and can cause explosion if not treated properly. The factors affecting landfill gas migration are liner systems, final cover, site geology and soil characteristics, age and characteristics of waste, depth of groundwater, and the LFG control system.

For greenhouse gas mitigation purposes, the landfill gas needs to be flared or recovered. Landfill gas flaring is not recommended for Dar es Salaam, as it would only increase the operation costs without generating any revenues. However, from a climate perspective this might be more desirable than continue the current dumping process. The landfill gas collection system consists of perforated plastic pipes which are horizontally or vertically installed below the ground surface or continuously within the landfill upon completion of a specific area. Nevertheless, investment costs of landfill construction are much lower without a full-scale LFG system and only gas flaring, or an alternative methane oxidation layer. In the case of Tanzania, it is highly recommended to implement national and local regulations to incentivize LFG utilization\textsuperscript{23} (although, unfortunately, there is no market for LFG utilization for electricity of direct use).

During the operation phase, continuous landfill gas monitoring is necessary in order to avoid explosions and to implement odor control when necessary. Sampling can be taken directly at gas wells or using techniques which


\textsuperscript{23} Munavar, Edi; Fellner, Johann; “Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country”, Austria, International Solid Waste Association (ISWA), 2013
satisfy the competent authority. The volatile organic compound compositions in landfill gas must then be subjected to occupational and environmental health risk assessments24.

Gas migration control is possible with passive systems (well vents, trench vents, low permeability barriers) or active systems (perimeter vacuum curtains, blower, LFG collection systems). An example of a gas collection system with wells is shown in Figure 8.

When considering the landfill gas collection system design, odor control, LFG migration control, reduction in surface emissions, protection of final cover and the minimization of the stress of surrounding vegetation need to be accounted for.

**Final cover System and Landfill Aftercare**

After the landfill cell(s) reach their final capacity, the waste needs to be covered with an intermediate cover, which can be soil or compost in the case of Dar es Salaam. The intermediate cover layer needs to have a minimum thickness of 50 cm and is required to prevent erosion, reduce water infiltration (thus leachate generation), gas emissions, promote the growth of vegetation and minimize aesthetic issues. After 5-20 years the intermediate cover should be replaced by a final cover, which is another thick layer (more than 50 cm) of clay or soil. Figure 9, shows examples of landfills with final covers. Planning for the landfill closure must include the environmental assessment and detailed investigation of the site.

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Figure 9. Landfill sites with final cover
The final cover will depend on the landfill configuration. Typical landfill configurations can be a) Area fill, b) Trench fill, c) Above and below ground fill, d) Valley fill, as shown on Figure 10. Sufficient surface slope should (more than 5 %) and dense vegetation cover to prevent erosion are recommended for the final capping\textsuperscript{25}. Final cover needs to be continuously inspected. If cracks appear they can be filled with soil, erosion damage needs to be repaired, low areas re-graded to prevent ponding and if there is visible smoke, a 60 cm soil layer can be added.

The landfilling methodology and the specifications of the final cover will be based on geological, geographical and hydrogeological conditions of the specific site. The technology will also be influenced by the leachate generation potential and other waste composition features.

A minimum landfill technology (e.g. liner, leachate treatment system) can be pre-set by national regulations, however in Dar es Salaam there is currently no such legislation.

**Further infrastructure and facilities at the landfill site**

Apart from the waste disposal area, the physical layout of the landfill must be defined and infrastructure and facilities considered in detail. Such infrastructure would be:

- Roads (all weather access roads and dirt roads for heavy machinery)
- Drainage to divert rain water
- Fencing, gate and signs
- Material storage area or areas for the informal sector workers

\textsuperscript{25} Munavar, Edi; Fellner, Johann; “Guidelines for Construction and Operation Municipal Solid Waste Landfill in Tropical Country”, Austria, International Solid Waste Association (ISWA), 2013
- Buffer zones (to isolate the site)

The following facilities are important to account for:
- Buildings for office, sanitation, employees, maintenance and garage facilities
- Utilities, such as power generator
- Scale, with suitable size and access roads
- Transfer station (if needed).

**Operation and monitoring**

For planning new landfills, operational and monitoring considerations need to be taken into account. Sound operations are important to minimize or eliminate impact on adjacent properties, reduce operating costs, increase landfill capacity (i.e. extend the lifetime of the landfill), create and maintain good public relations, reduce conflicts with regulatory agencies, reduce accidents, claims and liability, and demonstrate capability to operate new or expanded facilities.

Although the scope of this report is limited to the design, the main considerations of operation and monitoring are listed below:

**Technical operation:**
- Equipment for waste disposal (such as dozers, compactors, loaders, scrapers, road grader, excavators and articulate dump trucks)
- Pre-operational, during operation and post-operational maintenance of equipment and supporting equipment (e.g. water wagons)
- Waste processing equipment (screeners, etc.)
- Working face management (e.g. proximity of tipping area, accessibility in rainy seasons, contingency plan for accidents)
- Daily cover (soil or alternative material)
- Waste placement methodology
- Compaction of waste
- Temporary roads and infrastructure
- Safety and security
- Stormwater management
Monitoring:

Operations monitoring needs to include landfill gas generation and utilisation, leachate, air, groundwater, settlement, moisture and temperature monitoring. Some of these factors have already been mentioned in the document.

Environmental factors

It is important that pollution and other non-desired activity is prevented, therefore measures need to be taken towards noise control, odor control, fire control, dust control, litter control and pest control.

Trip to Addis Ababa, Ethiopia

6-9 August, 2017

The purpose of the trip to Ethiopia was to visit the City of Addis Ababa, who has been a CCAC MSWI member and has finished constructions of a new sanitary landfill in 2015. The new landfill site started operations in December 2015, however a few months after its start the operators encountered problems. The ISWA experts, Md Sahadat Hossain, professor at the University of Arlington in Texas, and David Dugger, landfill manager of the City of Denton, along with ISWA staff were invited to visit the landfill and consult the site operators. The trip to Addis Ababa was followed by the main mission, which was to hold a 2.5 days’ workshop on landfilling within the Work Plan project framework of Dar es Salaam in Tanzania.

The construction phase of the new landfill in Addis was supported by the US EPA through the CCAC MSWI City Work programme. Unfortunately, after a few months of operation the new landfill had to be shut down, due to demonstrations. Farmers who owe land around the site or who’s land was taken due to the landfill constructions have not been compensated for their property and therefore blocked the roads leading to the new landfill, thus preventing the operation of the site. The government reacted in a non-supportive way and the demonstrations have been continued for a longer period. The old Koshe dumpsite was used to dispose the waste generated in Addis. However, this situation is not sustainable on the long term, due to the limited space and safety issues.

The ISWA team conducted meetings with the City Manager and City Engineer of Addis Ababa and with the landfill manager and staff from the site. Additionally, meetings were arranged with the Horn of Africa Regional Environmental Center and Network (HoA-REC&N) who is also responsible for operating and improving the landfill site. At the time of the visit the leachate treatment pond was one of the difficulties making operations challenging. Although the landfill was not being used, due to the wet weather the leachate pond was full and a certain amount of the leachate generated needed to be taken out and transported to storage. This was necessary so that the leachate treatment pond is not filled over its maximum capacity.

The purpose of the meetings with HoA-REC&N was also to potentially set up an African Network which would be a project for the CCAC MSWI. The association has valuable connection and effective cooperation with

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26 Despite of this fact, the demonstrations went on for a long time. A dramatic landfill slide occured in March 2017 at the old Koshe dump, which killed over 100 people and triggered an international media response. http://www.aljazeera.com/news/2017/03/landslide-ethiopia-garbage-170312105503073.html
surrounding countries and also aims to be a regional center of the Solid Waste of Sustainability Institute (SWIS), based in Arlington, Texas.

Training on Technical and Managerial Aspects of New Sanitary Landfill Construction and upgrades to the Pugu dumpsite, Dar es Salaam, Tanzania

10-11-12 August, 2017

The main purpose of the mission trip was to organize a training focusing on current and future operations of the Pugu dumpsite and address the needs identified by Dar es Salaam city officials earlier, that is to train staff about the construction and operation of a new sanitary landfill.

The training was organized over 2.5 days, including a site visit to the Pugu Kinyamnezi dump and interactive discussions with breakout groups. The events were attended by a variety of stakeholders from the public and private sector.

Workshop participants:

- Ms Aisa Oberlin, Dar Institute of Technology
- Mr Alexander Fecher, Dar es Salaam City Council
- Mr Anthony Kilimo, Dr, Dar Institute of Technology
- Mr Deogratius Bernado, BORDA
- Mr Ezra Guya, Municipality of Kinondoni
- Ms Fatuma Duhu, Municipality of Ilala
- Mr Frederick Salukele, Ardhi University
- Ms Immaculate N Simiyu, Waste Management Section, National Environmental Management Authority (NEMC)
- Ms Kassim Salha, Dr, Dar Institute of Technology
- Mr Kitururu, Municipality of Kinondoni
- Mr Richard Kishere, Dar es Salaam Citz Council
- Mr Pius W. Mwalupembe, Municipality of Ilala
- Ms Sarah Mwakijdo, Municipality of Ilala
- Mr Boniface Bonimwambene, Eng. Dar es Salaam City Council
The first day of the training encompassed an opening keynote from the City Engineer of Dar es Salaam City, introduction of the participants and the experts and basic overview of waste management and landfill operations. Besides the daily operations, such as working phase management, compaction, daily cover, and equipment management, the practice at the City of Denton landfill site was showcased. Further topics discussed were waste screening, health and safety, litter control and landfill fire control. The idea of a closure plan for an existing landfill, siting criteria for selection of a new site and the necessary area calculations were explained.

The second day started out with a presentation of Richard Kishere, the manager of the Pugu dumpsite, discussing problems of the current operations, such as the low quality of the roads, flooding problems in the rainy season, or the lack of proper leachate treatment and working phase. The presentation was followed by a site visit to Pugu, where an on-site discussion took place, lead by the ISWA experts. The participants visited a newly constructed landfill area, which was meant to be a sanitary landfill, however with a very limited capacity. The experts discussed the technical details of certain parts of the site, such as the concrete liner and the walls of the pit also made out of concrete. Moreover, the waste pickers were visited and their activities briefly discussed. Since the dumpsite does not have fencing or any or separation from its environment, the informal sector moves freely around the dump. The recyclable waste collected is traded to middle men, who are mostly Chinese and ship the recyclable waste to their country for further processing. The waste pickers earn approximately 7 USD per day, according to the dumpsite manager. Since the dumpsite is owned by the Dar es Salaam City Council, the waste pickers could be formalized and the city could charge them a certain fee for leaving them work on the dump. At the same time, it would be beneficial to gather them to a smaller area (such as a working phase) for a better control of their activities and protection of their health. Waste with a high amount of recyclables could be transferred to this specific part of the dumpsite and high organic content waste (such as waste from the markets) could be separately dumped. Such actions can be immediate and do not have a high cost.
After the site visit participants had a lively classroom discussion and training on the financial aspects of landfill operation, followed by debating the need to close Pugu and to open a new sanitary landfill instead. The overall conclusion, recommended by the experts was that Pugu still has capacity for the following 10+ years. Therefore, immediate and mid-term upgrades should be considered, including a proper partial remediation of the dump and also applying a liner so as to prevent further pollution to the ground. This idea to upgrade the Pugu dumpsite was also supported by other experts and institutions (such as the World Bank) who conducted studies of the waste management situation of the city earlier.\(^{27}\)

During the final day of the training the experts elaborated on the bottom liner design, leachate generation and collection, landfill gas basics and briefly introduced future trends, such as the sustainable material management, bioreactor, biocell operation or landfill mining.

The detailed AGENDA of the event can be found below. The main technical details of the training are summarized in the various chapters of this report.

The training received a very positive feedback from the event participants and further project stakeholders, who were updated on the training content, such as representatives from the Dar es Salaam City Council who were unable to participate.

The ISWA team received promises for further support and the participation of the City Directress for upcoming events of the CCAC MSWI Work Plan project for Dar es Salaam.

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\(^{27}\) Note: in September 2016 a delegation of the Dutch Ministry of Environment conducted a full scope waste management situation assessment in Dar es Salaam and reached the same conclusion on upgrading the Pugu dumpsite. The Dutch experts also proposed a roadmap on how to reach an integrated solid waste management system in the city and have been working on a cooperation with the city as a pre-requisite of the funding they plan to provide to implement the desired improvements. The work of the Dutch Delegation was currently on-going at the time of closing the CCAC Work Plan project for Dar es Salaam.
Training on Technical and Managerial Aspects of New Sanitary Landfill Construction and upgrades to the Pugu dumpsite

AGENDA

*Dar es Salaam, 10-12 August, 2016*

**Day 1 – Construction and Operation of the Pugu and City of Denton Landfill**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 – 8:30</td>
<td>Registration</td>
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<tr>
<td>8:30 – 9:00</td>
<td>Opening keynote speeches given by the Mayor and City Director of Dar es Salaam</td>
<td>Paul Stegmann, Kata Tisza, ISWA</td>
</tr>
<tr>
<td>9:00 – 9:20</td>
<td>Introduction of ISWA and CCAC</td>
<td>Paul Stegmann, Kata Tisza, ISWA</td>
</tr>
<tr>
<td>9:20 – 9:45</td>
<td>Introduction of SWIS Introduction of the Agenda for the upcoming 3 days</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
</tr>
<tr>
<td>9:45 – 10:30</td>
<td>Waste Management Overview, and Landfill Basics</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
</tr>
<tr>
<td>10:30 – 10:45</td>
<td>Break</td>
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<tr>
<td>10:45 – 11:45</td>
<td>Working Face Management-Compaction and Daily Cover, Equipment and Maintenance, Landfill Operation at City of Denton</td>
<td>David Dugger, Landfill Manager, City of Denton</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>Questions and Answers</td>
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<tr>
<td>12:00 – 13:00</td>
<td>Lunch</td>
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<tr>
<td>13:00 – 14:00</td>
<td>Waste Screening, Health and Safety, Litter Control and Landfill Fire Control</td>
<td>David Dugger, Landfill Manager, City of Denton</td>
</tr>
<tr>
<td>14:00 – 15:00</td>
<td>Landfill Closure Plan, New Landfill Siting Criteria and Required Area Calculation</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
</tr>
<tr>
<td>15:00 – 16:00</td>
<td>Questions and Answers and Closure of the Day</td>
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</tbody>
</table>

**Day 2 – On site training at the Pugu landfill**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 – 10:00</td>
<td>Daily Operation and Problems at Pugu Landfill</td>
<td>Richard Kishere, Landfill Manager, DCC</td>
</tr>
<tr>
<td>10:00 – 10:15</td>
<td>Break</td>
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<tr>
<td>10:15 - 13:00</td>
<td>Practical Training at the Pugu Landfill about Topics Discussed during the Trainings</td>
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<tr>
<td>13:00 – 14:00</td>
<td>Lunch</td>
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<tr>
<td>14:00 – 15:00</td>
<td>Financial Aspects of Landfill Operation</td>
<td>David Dugger, Landfill Manager, City of Denton</td>
</tr>
<tr>
<td>15:00 -16:00</td>
<td>Open Discussion on Closing of Pugu Landfill and Opening of a New Landfill</td>
<td>All</td>
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</tbody>
</table>

**Day 3 – Closing Down and Upgrading Pugu Landfill**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Facilitator</th>
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</thead>
<tbody>
<tr>
<td>8:30 – 9:30</td>
<td>Landfill Bottom Liner Design, Leachate Generation and Collection</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
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<tr>
<td>Time</td>
<td>Topic</td>
<td>Presenter</td>
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<tr>
<td>9:30 – 10:15</td>
<td>Leachate Management</td>
<td>David Dugger, Landfill Manager, City of Denton</td>
</tr>
<tr>
<td>10:15 – 10:30</td>
<td>Break</td>
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<tr>
<td>10:30 – 11:15</td>
<td>Landfill Gas Basics</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
</tr>
<tr>
<td>11:15 – 12:15</td>
<td>Future Trends-Sustainable Material Management, Bioreactor/ Biocell Operation and Landfill Mining</td>
<td>Dr. Sahadat Hossain, Director of SWIS, Professor at UTA</td>
</tr>
<tr>
<td>12:15 – 13:00</td>
<td>Questions and Answers – Open discussion</td>
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<td></td>
<td>Feedback survey</td>
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<tr>
<td>13:00 – 13:15</td>
<td>Closure of the 3 days training</td>
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<tr>
<td>13:15 – 14:30</td>
<td>Networking Lunch</td>
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ANNEXES

ANNEX I - International Guidelines for Sustainable Landfill Evaluation
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Open Dump</td>
<td>• No cover, steep slopes ≥ 4/1 (V:H), uncompacted waste, burning, birds, vectors, ponding, muddy conditions visible from property boundary.</td>
<td>• Rock, gravel, sand or undefined soils.</td>
<td>• Waste in direct contact with lake, ocean, stream, pond, or wetland.</td>
<td>• Rock, gravel, sand, or undefined soils.</td>
<td>• Large areas of exposed waste, minimal or no compaction.</td>
<td>• Provides valuable resource.</td>
<td>• Provides a local economic resource.</td>
<td>• Little or no legislation.</td>
<td>• No planning.</td>
</tr>
<tr>
<td></td>
<td>• Accepts uncovered vehicles hauling wastes.</td>
<td>• No liner, no leachate collection pipes.</td>
<td>• Waste in flood plain.</td>
<td>• No liner.</td>
<td>• Burning.</td>
<td>• Unhealthy environment.</td>
<td>• Cheap disposal option.</td>
<td>• Poor enforcement.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Extensive wind-blown debris, dusty off site.</td>
<td>• Distance ≤ 50 m to groundwater or unknown.</td>
<td>• Runoff from waste uncontrolled and directly to surface water body.</td>
<td>• No gas extraction</td>
<td>• No checking for and rejection of hazardous waste.</td>
<td>• Health and safety issues of serious concern.</td>
<td>• Significant health care costs due to higher incidence of diseases.</td>
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<td></td>
<td>• Major erosion problems, visible from off &amp; on site.</td>
<td>• Not arid or semi-arid.</td>
<td>• Distance &lt; 500 m to buildings or occupied areas.</td>
<td>• Distance &lt; 20 m to groundwater.</td>
<td>• No safety procedures, education, or control of workers.</td>
<td>• Site not secure.</td>
<td>•</td>
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<tr>
<td>Controlled Landfill (Controlled Open Dump)</td>
<td>• Waste compacted, but not totally covered &amp; visible from boundary.</td>
<td>• Silt or clay soils ≥ 5 m thick under waste.</td>
<td>• Waste does not contact any surface water other than rare flooding (&lt; 1 time/5 years).</td>
<td>• Silt or clay soils, no liner.</td>
<td>• Large areas of exposed waste, but incoming waste confined to specific working areas, other areas covered.</td>
<td>• No burning.</td>
<td>• Reduced scavenging.</td>
<td>• Increased operational costs.</td>
<td>• Basic environmental legislation.</td>
</tr>
<tr>
<td>1. Steep slopes &gt;3/1 (V:H).</td>
<td>2. No liner or leachate collection pipes.</td>
<td>3. Runoff from waste channeled, but direct to surface water body.</td>
<td>4. Distance &gt; 20 m to groundwater.</td>
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</tr>
<tr>
<td>• Steep slopes &gt;3/1 (V:H).</td>
<td>• No liner or leachate collection pipes.</td>
<td>• Runoff from waste channeled, but direct to surface water body.</td>
<td>• Minimal education or control of workers, few safety procedures.</td>
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<tr>
<td>• Birds &amp; minimal vector control.</td>
<td>• No groundwater monitoring, but no groundwater use within 1 km.</td>
<td>• Distance &gt; 20 m to groundwater.</td>
<td>• Minimal education or control of workers, few safety procedures.</td>
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</tr>
<tr>
<td>• Some muddy roads.</td>
<td>• Erosion channels, some ponding &amp; muddy conditions visible from off site.</td>
<td>• No buildings at distance &lt; 500 m from waste, or if so, monitor gas between landfill and buildings.</td>
<td>• Some muddy areas and ponding, but not where workers are.</td>
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</tr>
<tr>
<td>• Some muddy roads.</td>
<td>• Interior slopes not steep &lt; 4/1 (V:H).</td>
<td>• No burning.</td>
<td>• Interior slopes not steep &lt; 4/1 (V:H).</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>• Periodic wind-blown debris &amp; dusty off site.</td>
<td>• Some animal and vector control.</td>
<td>• Accepts uncovered vehicles hauling wastes.</td>
<td>• Some animal and vector control.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Erosion channels, some ponding &amp; muddy conditions visible from off site.</td>
<td>• Site limited with a fence.</td>
<td>• No burning.</td>
<td>• Site limited with a fence.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>• No burning.</td>
<td>• Accepts uncovered vehicles hauling wastes.</td>
<td>• Interior slopes not steep &lt; 4/1 (V:H).</td>
<td>• Some animal and vector control.</td>
<td></td>
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<tr>
<td>• Accepts uncovered vehicles hauling wastes.</td>
<td>• Site limited with a fence.</td>
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<tr>
<td>Sanitary Landfill</td>
<td>• Exterior slopes covered &amp; vegetated, maximum slope 1:2 (V:H), recommended slope 1:3 (V:H).</td>
<td>• Fully lined for municipal solid waste landfills (non-hazardous waste) and hazardous waste landfills.</td>
<td>• Totally isolated from water surface, wetland, or flood plain.</td>
<td>• Fully lined landfill and ≥ 1 m or 5 m clay soils according to class of landfill.</td>
<td>• Waste covered except at working face, which is covered daily.</td>
<td>• Free from trespassers and scavengers.</td>
<td>• Specific legislation and regulation, namely EU Directive 1999/31/CE.</td>
<td>• Planning and permit requirements.</td>
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<tr>
<td></td>
<td>• Roads free of mud, dust &amp; debris.</td>
<td>• Full leachate collection system, treatment and monitoring.</td>
<td>• Area of landfill not in low area with historical wetland or flood plain.</td>
<td>• Active gas extraction for flare or use.</td>
<td>• No burning.</td>
<td>• Site secure.</td>
<td>• Revenue from landfill gas valorisation.</td>
<td></td>
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<tr>
<td></td>
<td>• No wind-blown dust &amp; debris except in rare conditions.</td>
<td>• No groundwater use within 500 m of waste.</td>
<td>• All waste contact runoff collected &amp; treated, waste area surrounded by road sides.</td>
<td>• Distance &gt; 300 m to buildings, full gas monitoring system in buildings and soils.</td>
<td>• Careful checking on waste acceptance and, according to the landfill class, routine rejection of hazardous or unwanted waste.</td>
<td>• Cost for leachate treatment.</td>
<td>• Cost for leachate treatment.</td>
<td></td>
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<td></td>
<td>• No erosion, no vectors, minimal birds.</td>
<td>• Full groundwater monitoring (at least every six month) in the</td>
<td>• Other runoff to sedimentation pond for discharge.</td>
<td>• Land use control within 1 km of landfill.</td>
<td>• All interior slopes &lt; 4/1 (V:H).</td>
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<td></td>
</tr>
<tr>
<td>Bioreactor Landfills</td>
<td>Exterior slopes covered &amp; vegetated, no steeper than 1:3 (V:H).</td>
<td>Plastic and/or ≥ 1 m thick clay liner for MSW landfill.</td>
<td>Totally isolated from water surface, wetland, or flood plain.</td>
<td>Fully lined landfill and/or ≥ 5 m clay soils.</td>
<td>Waste covered except at working face, which is covered daily.</td>
<td>Free from trespassers and scavengers.</td>
<td>Variable charges for waste types.</td>
<td>Planning and permit requirements.</td>
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<td></td>
<td>Roads free of mud, dust &amp; debris.</td>
<td>Full leachate collection system and monitoring.</td>
<td>Area of landfill not in low area with historical wetland or flood plain.</td>
<td>Active gas extraction for productive use; Design and operation to increase gas recovery.</td>
<td>No burning.</td>
<td></td>
<td></td>
<td>Exclusion of wastes toxic to bioreactor.</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Incoming waste confined to one working area and compacted immediately.</td>
<td></td>
<td></td>
<td>Control of wastes with rapid biodegradation.</td>
<td></td>
</tr>
</tbody>
</table>

- No burning, minimal odours.
- Waste confined to one working face, compacted immediately, and covered daily.
- Surface water controlled, no ponding.
- Unaccepted uncovered vehicles hauling wastes.
- No on-site ponding.
- Worker safety training and procedures operational.
- Dust and vector controls operational.
- Site limited with a fence.
- Site secure.
- Aftercare provision necessary for an extended period.
- Roads free of mud, dust & debris.
- Full leachate collection system and monitoring.
- Area of landfill not in low area with historical wetland or flood plain.
- Active gas extraction for productive use; Design and operation to increase gas recovery.
- Waste covered except at working face, which is covered daily.
- No burning.
- Incoming waste confined to one working area and compacted immediately.
- Free from trespassers and scavengers.
- Variable charges for waste types.
- Planning and permit requirements.
- Exclusion of wastes toxic to bioreactor.
- Control of wastes with rapid biodegradation.
| • No wind-blown dust & debris except in rare conditions. |
| • Recirculation of leachate with consideration of nitrogen treatment. |
| • All waste contact runoff collected & treated, waste area surrounded by roadsides. |
| • Control of gas emissions from border and above cap with flares and/or methane oxidation. |
| • Careful checking and routine rejection of hazardous or unwanted waste. |
| • Recognition of sequestration benefits of non-degraded carbon wastes. |
| • No erosion, no vectors, minimal birds. |
| • No groundwater use within 500 m of waste. |
| • Other runoff to sedimentation pond for discharge. |
| • Distance > 300 m to buildings, full gas monitoring system in buildings and soils. |
| • All interior slopes < 4/1 (V:H). |
| • Acceptance of wet wastes within broader moisture management program. |
| • No burning, minimal odors. |
| • Full groundwater monitoring. |
| • No on-site ponding. |
| • Land use control within 1 km of landfill. |
| • Worker safety training and procedures operational. |
| • Surface water controlled, no ponding. |
| • Treatment of excess leachate. |
| • Intermediate cover designed to limit gas emissions from active landfill. |
| • Dust and vector controls operational. |
| • Site limited with a fence. |
| • Waste confined to one working face, compacted immediately, covered daily. |
| • Joint design of gas, leachate collection, and leachate recirculation systems. |
| • Site limited with a fence. |
| • Land use control within 1 km of landfill. |
| Sustainable landfill | • Exterior slopes covered & vegetated, no steeper than 1:3 (V:H) (long term geotechnical stability ensured). | • Plastic and/or ≥ 1 m thick clay liner. | • Totally isolated from water surface, wetland, or flood plain. | • Fully lined landfill and/or ≥ 5 m clay soils. | • Waste covered except at working face, which is covered daily. | • Free from trespassers and scavengers. | • Planning and permit requirements. |
| | • Roads free of mud, dust & debris. | • Full leachate collection system, treatment and monitoring. | • Area of landfill not in low area with historical wetland or floor plain. | • Active gas extraction for flare or use. | • No burning. | • Site secure. | • Possibilities for recovery of waste (resources) - landfill mining. |
| | • No wind-blown dust & debris. | • No groundwater use. | • All waste contact runoff collected & treated, waste | • Distance > 300 m to buildings, full gas monitoring | • Incoming waste confined to one working area and compacted immediately. | • Careful checking and routine rejection of | • Monitoring and modelling of settlement. |
| | • Control of fire hazards of bioreactor operation. | • Ongoing leachate quality measurement to assess biodegradation. | Monitoring and modelling of moisture balance. | | | | |
| · No erosion, no vectors, no birds. | · Full groundwater monitoring. | · Other runoff to sedimentation pond for discharge. | · Overall landfill gas collection rate >90%. |
| · No burning, no odours. | · Long term safety of groundwater. | · No on-site ponding. | · Minimization of residual landfill gas emissions by microbial methane oxidation in landfill cover systems. |
| · Waste confined to one working face, compacted immediately, covered daily | · Long term safety of surface water. | · Land use control within 1 km of landfill. | · Dust and vector controls operational. |
| · Surface water controlled, no ponding. | · Unacceptable uncovered vehicles hauling wastes. | · Waste of no or low reactivity. | · Site limited with a fence. |
| · Worker safety training and procedures operational. | · Waste confined to one working face, compacted immediately, covered daily | · Surface water controlled, no ponding. | · Unacceptable uncovered vehicles hauling wastes. |
ANNEX II. - Greenfield Matrix – for landfill site selection process
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Recommendation</th>
<th>Grading Scale</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Haul Distance</td>
<td>Minimum haul distance is desirable.</td>
<td></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>Site 1 and 3 within 10 miles radius from collection points, Site 2 within 15 miles radius from collection points.</td>
</tr>
<tr>
<td>2 Location Restrictions</td>
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<tr>
<td>2.1 Airport Safety</td>
<td>• New MSW landfills within 8 km (5 mile) radius of any airport: Turbojet Aircraft &amp; Piston Type Aircraft &lt;br&gt; • Landfill within 10,000 ft (3000m): Turbojet Aircraft &lt;br&gt; • Landfill within 5,000 ft (1500m): Piston Type Aircraft</td>
<td></td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>Site 1 has a private airport 2000 m away from the site location. No nearby airport within 3000 m for Site 2 and Site 3.</td>
</tr>
<tr>
<td>2.2 Flood Plains</td>
<td>Landfill will not restrict the flow of the 100-year flood</td>
<td></td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>Site 3 is within 100 year floodplain but site 1 and site 2 is not within any 100 year floodplain area.</td>
</tr>
<tr>
<td>2.3 Wetlands</td>
<td>• Must not be located in wetlands &lt;br&gt; • Must not violate state water quality standard and toxic effluent standard or prohibition &lt;br&gt; • Must not jeopardize the continued existence of endangered or threatened species or critical habitats &lt;br&gt; • Must not require any requirement for the protection of a marine sanctuary</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>None of the sites are located in wetlands.</td>
</tr>
<tr>
<td>2.4 Fault Areas</td>
<td>Must not be located within 200 feet (60 meters) of a fault</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>None of the sites are located within 200 feet (60 meters) of a fault.</td>
</tr>
<tr>
<td>2.5 Seismic Zones</td>
<td>10%&gt; probability that the maximum horizontal acceleration will exceed 0.1g in 250 years</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>None of the sites are located in seismic zone.</td>
</tr>
<tr>
<td>2.6 Unstable Area</td>
<td>Steep slopes, Liquifiable soils</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>None of the sites are located in unstable area.</td>
</tr>
<tr>
<td>3 Available Land Area</td>
<td>to have enough area, including an adequate buffer zone, to operate a site for at least five years</td>
<td></td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>Site 1 and Site 3 has major highways and local roads to access the site. The adjacent road condition for site 1 is very good and has a speed limit of 30 mph. The local roads near site 3 is in acceptable conditions however might need some additional improvement for high volume of traffic for the landfill. Site 2 is also located near major highway however the access roads are rural hogways and needs major improvement.</td>
</tr>
<tr>
<td>4 Site Access</td>
<td>Must be accessible from all part of the city. Located near major highways and the road conditions are good close to the landfill.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5 Soil Conditions and Topography</td>
<td>Soil test is required for cover soil</td>
<td></td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>Based on available soil data and soil information available, the soil underneath the sites are sandy or silty loam. The soil properties were similar for all the sites.</td>
</tr>
<tr>
<td>6 Climatologic Conditions</td>
<td>• Winter and wet weathers &lt;br&gt; • Wind strength and wind patterns</td>
<td></td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>All three sites are located in similar climatologic conditions. The sites are exposed to high wind velocity.</td>
</tr>
<tr>
<td>7 Surface Water Hydrology</td>
<td>Must limit storm water runoff flow into the landfill</td>
<td></td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>Drainage needs improvement for all three sites.</td>
</tr>
<tr>
<td>8 Geologic and Hydrogeologic Conditions</td>
<td>• Significant thickness of unsaturated zone beneath Landfill &lt;br&gt; • Underlain by Strata with low hydraulic conductivity &lt;br&gt; • Does not intercept any sole source or usable Aquifer &lt;br&gt; • Located outside floodplain areas &lt;br&gt; • Has adequate set back from populations, lakes, streams, and wetlands</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Water table is 12 ft below site 1, 9.8 ft below site 2 and 15 ft below site 3. However, the design of sanitary landfill liner will prevent any groundwater contamination from landfill operation.</td>
</tr>
<tr>
<td>9 Local Environment</td>
<td>Landfill must be planned and operated to be environmentally acceptable with respect to traffic, noise, odor, dust, airborne debris, visual impact, vector control, and surrounding property values.</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>All three sites are located far from the locality and the adjacent lands are used for commercial purposes. There is no school, park, religious institutions near any of the sites.</td>
</tr>
<tr>
<td>10 Ultimate Use for the Completed Landfill</td>
<td>As recreation sites, sport fields, and parking areas.</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>The post closure use of the proposed landfill is playground.</td>
</tr>
</tbody>
</table>

Total Score: 60 62 61
ANNEX III. – Separation, sorting and composting of municipal solid waste at the Pugu dumpsite in Dar es Salaam