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# Abstract

The objective of this project is to promote best available techniques and best environmental practices (BAT/ BEP) to reduce unintentionally released Persistence Organic Pollutants (u-POPs) generated from open burning of waste in the two biggest dumpsites in Lesotho, one in the city of Maseru (Tšosane dumpsite ) and another in the town of Maputsoe (Mokotakoti dumpsite). Data collected from a preceding project, site visits and survey of related literature were used to formulate a life cycle assessment of waste life in the municipalities and to inform formulation of best waste management practices. The open burning of waste was found to be a great threat especially to people living in areas surrounding the dumpsites, specifically the Tšosane dumpsite in Maseru which has recently experienced an outburst of a severe fire and smoke for weeks. A manual giving a broad picture on how best to organize collection and recycling of major forms of waste in the two municipalities is recommended, along with a recommendation on the need for a specific policy on the handling of diapers which might present a major headache for the already stretched dumpsites in the future.

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# 4. Introduction

The concepts of Best Available Techniques and Best Environmental Practices (BEP/BAT) are a priority in the aim to reduce or eliminate, where practical, the unintentionally produced persistent organic pollutants (u-POPs) such as dioxins from open burning of waste. U-POPs can be found in many products that are used on daily basis some of which have been added to improve the characteristics of such products. They may also result as byproducts of various industrial processes.

United Nations Industrial Development Organization (UNIDO) is one of the organizations taking the lead in addressing the problem of (u-POPs) across the world. UNIDO seeks to reduce POPs due to their harmful effects on human health and the environment. Among others, the POPs harmful effects include reproductive disorders, increased cancer risk, genotoxicity and increased birth defects, endocrine disruption, and neurobehavioral impairment.

Lesotho as one of the participating African countries of SADC sub-region in this effort, has selected two municipalities that host the two largest dumpsites in the country to implement the concepts of BAT/BEP. The main objective of this project is to reduce the negative effects of open burning practices that normally take place every day in the dumpsites. The two selected municipalities are known to host the two largest dumpsites in the country and they accept various kinds of municipal waste whose fate is normally random or spontaneous burning. These wastes are considered among the main sources of u-POPs.

The project will prioritize two large dumpsites in Lesotho which are Ha-Tšosane Dumpsite in Maseru and Mokotakoti Dumpsite in Maputsoe. These dumpsites were highlighted by National Implementation Plan for the Stockholm Convention (NIP) as needing a special attention by the government since they both receive significant and high amounts of waste due to proximity to developed industrial activities. We seek to review current waste management practices in the dumpsites and recommend best possible waste management setups with a special attention to what is technically and economically feasible and not feasible given the context of Lesotho.

# 5. Project Goals

The project seeks to achieve the following:

*a)* Observe the current status quo regarding the open burning of waste in selected municipalities in Lesotho and assess its fate through a limited Life Cycle Assessment tool.

*b)* Provide scientifically based recommendations for implementing the most appropriate measures in minimizing open burning activities in the Tšosane (Maseru) and Mokotakoti (Maputsoe) dumpsites.

*c)* Strengthen the selected municipalities in developing action plans for Environmentally Sound Management (ESM) and reduction of u-POPs releases from open burning of waste and assist them in introducing waste management plans with BAT/BEP in through provision of broad implementation manuals.

Using the information collected in the preliminary stage of the project, the goals of this report are achieved through recommendations on:

*a)* *Recycling Centres and associated Deposit-Refund Schemes:* A network of Collection Centres (CCs, the satellites) around Central Collection and Recycling Centres (CCRCs) and the use of deposit refund schemes are proposed based on the observations of the nature of the current handling of waste in the two selected municipalities and potential rooms for improvements.

b) *Turning waste into useful products:* specific manuals are presented based on how best to handle and recycle major forms of waste which are paper, plastic and textile discards. Effort is made to help explain the nature of this waste and how it can be successfully recycled in the context of Lesotho.

c) *Policy recommendation:* A single policy on how best to handle especially diapers waste is briefly recommended.

## 6. Methodological Approach

The author relied on the extensive baseline data needed which was already extensively collected on the study called "Promotion of BAT and BEP to reduce u-POPS Releases from Waste open Burning in Lesotho."[1] That data included waste analysis and characterization at the two dumpsites. It was based on extensive consultations with the two municipalities' operation teams and interviews with different households and textile manufacturers in both town councils.

The life cycle analysis was made through visits to the municipalities and observation of various means in which the waste is currently handled throughout different stages of its life-cycle. Such visits also included observations on the extent of dumpsites protection, proximity of the sites to residences and water streams, the qualitative probability of the life-span of the site. One trip was also taken to Kwazulu Natal, South Africa, to observe

[1] Thimothy Thamae (2018), "Promotion of BAT and BEP to reduce u-POPS Releases from Waste open Burning in Lesotho," submitted to the Government of Lesotho Department of Environment and the United Nations Industrial Organization (UNIDO).

the handling of textile waste by what seemed to be the only company in South Africa recycling such waste.

Using the above information and the lessons learned from it, and best practices from literature (some of which is reflected on the Bibliography), were formulated for the development of waste management guidelines and practices.

# 7. Lessons learned from the two municipalities

## *Lifecycle Assessment of waste in the two municipalities*

### *The general picture*

Life Cycle Assessment (LCA) is a commonly used tool for assessing the environmental and practical impacts associated with a product. It traces the life of a product and its impacts in major stages of its life-time. LCA is generally adopted to analyze environmental burden of waste management technologies. In this study, we make a very limited LCA that will shed an idea into the pathways of waste generated in the two municipalities and impacts of such waste on the environment.

In the area of waste, the lifecycle starts once a product becomes waste (once it is discarded in a waste bin). Discards in both municipalities are normally put in mixed waste bins of all kinds, whether in household, commercial or industrial settings. Only in rare cases do separate waste bins get used to differentiate the waste. In most households, the waste is either burned at home or collected to dumpsites either with the help of municipalities' collection trucks or through the use of private collectors. Commercial and industrial outlets rarely to in-house burning, choosing, instead, to either sell to amateur recyclers or send it to dumpsites.

As the waste reaches the dumpsite, further separation takes place, a more orderly one in Ha Tšosane dumpsite at Maseru municipality and a chaotic one in Mokotakoti dumpsite in Maputsoe. The waste separation at the dumpsite is highly dependent on the type of recyclable waste that is in demand at a particular period. If there are paper buyers, the waste pickers separate paper from the rest of other waste to sell it. The waste that is not in demand at that particular time simply remains at the dumpsite. Biodegradable waste will decompose after a certain time while non-biodegradable waste will just remain on the top soil. From decomposed waste, leachates may result thus polluting nearby sources of water. Figure 1 reveals the kind and distribution of waste that finally makes its way to both dumpsites.

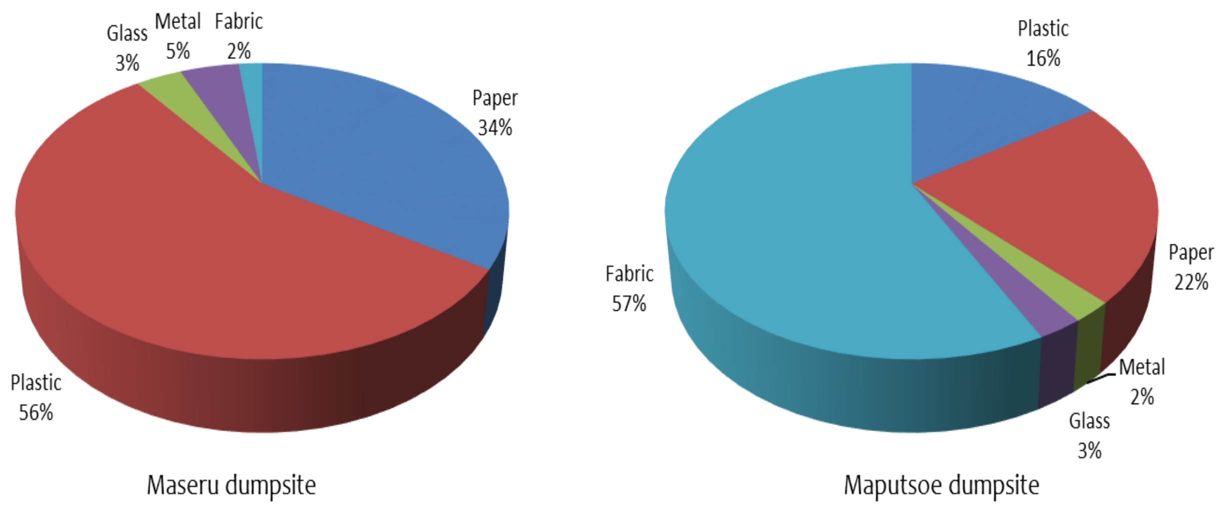


*Figure 1: Waste composition of Maputsoe and Maseru Dumpsites*

In Figure 2, a generalized life-cycle of Municipality Solid Waste (MSW) is shown. The blue boxes show different stages through which waste goes whereas the red boxes show the products from each treatment phase. The green boxes show the residue resulting from treatment phases. The MSW ceases being waste once it is recovered or recycled into a useful product, or once it becomes a residual landfill product or emitted to air or water. The inputs and outputs of each phase further considered below, and relevance to the two municipalities is considered.

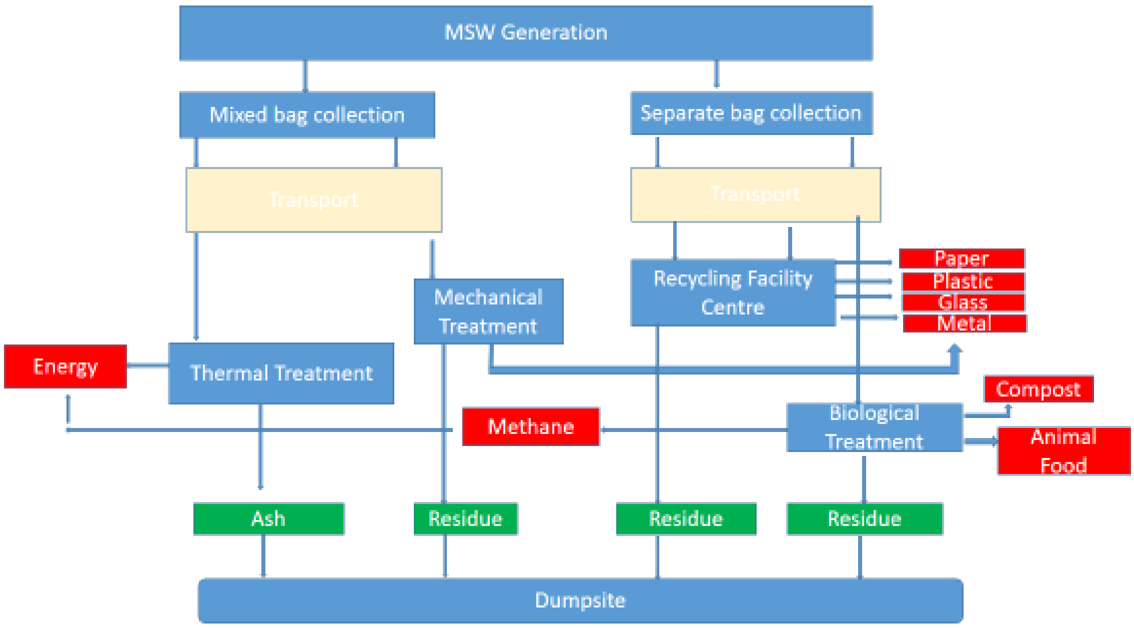


*Figure 2: A typical lifecycle of Municipality Solid Waste (MSW)*[2]

*Thermal treatment*

This is the stage at which waste is incinerated. Any kind of fuel could be used to start the fire. The chemical reaction between the fire and the MSW, result in release of u-Pops and other outputs as shown in Figure 3. In Maseru and Maputse Municipalities, waste burning is not a coordinated process. Usually, it is a result of random burning by arsons in the unprotected dumpsite of Maputsoe and outbursts of methane releases and a combination with heat in the case of Ha Tšosane dumpsite in Maseru. It is also practiced by households reluctant or unable to ship their waste to the dumpsites. For whatever reason the burning occurs, u-Pops are part of the releases.

[2] (Figures 2-4) Konstadinos Abeliotis (2011), Life Cycle Assessment in Municipal Solid Waste Management, Integrated Waste Management - Volume I, in Sunil Kumar (Ed.), ISBN: 978-953-307-469-6,


*Figure 3: Thermal Treatment of waste*

*Biological Treatment*

In this treatment, the major inputs are organic waste and water and sometimes even electricity (Figure 4). After organic matter has been treated, compost, which is a useful agricultural product, is yielded. But compost is not the only output, other undesirable products such as leachates and exhaust gases result. For the dumpsites in the two local municipalities, all kinds of organic waste are delivered, including mainly food waste and filled diapers. There is no special effort to retrieve this waste and it may be responsible for frequent outbursts of spontaneous fire at Ha Tšosane dumpsite in Maseru as it decomposes into combustible methane.


*Figure 4: Biological Treatment of Waste*

*Mechanical Treatment*

In the two municipalities, the waste is usually transported in mixed bags. As these bags arrive at dumpsites, waste pickers physically separate the waste that is currently in demand in the market for sale. As for other unwanted waste, it simply remains at the dumpsite as residue. This kind of waste handling is practiced at the dumpsites of both municipalities although it is much more organized at Ha Tšosane.

### *The Nature of Ha Tšosane and Mokotakoti Dumpsites*

The two dumpsites are differently protected. The Mokotakoti dumpsite in Maputsoe is hardly fenced. It does seem to have been previously fenced but the fence has been torn apart. The Tšosane dumpsite is completely fenced and the fence is impenetrable, making it difficult for trespassers. Conversely, Mokotakoti dumpsite has a good distance from nearby built-up area while the Tšosane dumpsite is right inside the built-up area and the many houses are only a few meters away. The result of this close proximity and Tšosane's outbursts of fires, albeit infrequent, has affected people in the area adversely. That is because when the fires do happen, it sometimes takes weeks to put it off, with people enduring the worst kind of smoke inhalation day in and day out. The latest and probably one of the worst episodes occurred just a year ago.

Whereas the Tšosane dumpsite is a bit distant from the nearby Maqalika dam, it does appear to be on the same basin with the dam and it is highly possible that all its leachate ends up in the dam that supplies water to the city of Maseru. Mokotakoti dumpsite is too close to the nearby Mohakare river, which forms the border between Lesotho and south Africa. However, the dumpsite does not carry as much waste as its Maseru counterpart, and probably offers fewer releases as a result.

While the Mokotakoti dumpsite still has a room for more waste, it is a fair assessment to conclude that the Tšosane dumpsite may as well be in the twilight of its life although the city does not seem to have a sense of urgency to replace it with a viable alternative.

## *Volumes, distribution, handling and transactions of waste within the two municipalities*

### *Waste handling and transactions within Maseru City Council (MCC)*

In the Maseru City Council (MCC) most households confirmed that they incinerate their waste (mostly plastic and paper) and few people are taking their waste to the dumping site.  As for metal waste, most of it is being collected by individuals who sell it to the local buy-back centres. These metal collectors then sell it to the recycling companies in South Africa. Some people also collect glass bottles to sell them locally for recycling purposes.

The waste at the dumpsite comes mainly from commercial and institutional places. The higher percentage of waste at dumpsite was found to consist of plastic at 60% by volume. It was followed by paper at 37% then few of other forms of waste. Even though tons of textile waste is produced on daily basis by the textile manufactures, only traces of textile off-cuts were found at the dumpsite. The reason is that most of the manufactures either burn their waste or give it to recyclers, one of defibrillate it and ship it to China.

Demand of recyclable waste at the Tšosane Dumpsite fluctuates at different periods. It depends on what the buyers' interests are at a given time. When it is a good period for paper, plastic is just left there and sometimes deteriorates in quality on the dumpsite. Eventually the waste that is collected at the dumpsite by the waste pickers is sold to collectors who normally ship it to South Africa for recycling. The reality is that the incoming waste is overwhelming to an extent that only a fraction of it is taken by the recyclers while most of it is left behind at the dumpsite with an extremely limited capacity. This is why we think the dumpsite is getting out of control.

### *Waste distribution and volumes produced within areas served by MCC*

Generally, waste generated by MCC was found to consist mainly of plastic 37.1 and paper 36.1 (Figure 5). Glass and metal are found in very small quantities, 5.1 and 2.2 respectively. Total amount of recyclable waste per week is estimated to be 2,008 $m^3$, of which plastic was found to be 1,359 $m^3$, paper 1,497 $m^3$, glass 185 $m^3$ and metal 76 $m^3$. From the total estimate, the households were found to contribute 45%, commercial 40% and then institutional facilities 13%. These estimations were established from the surveyed areas served by Maseru City Council.

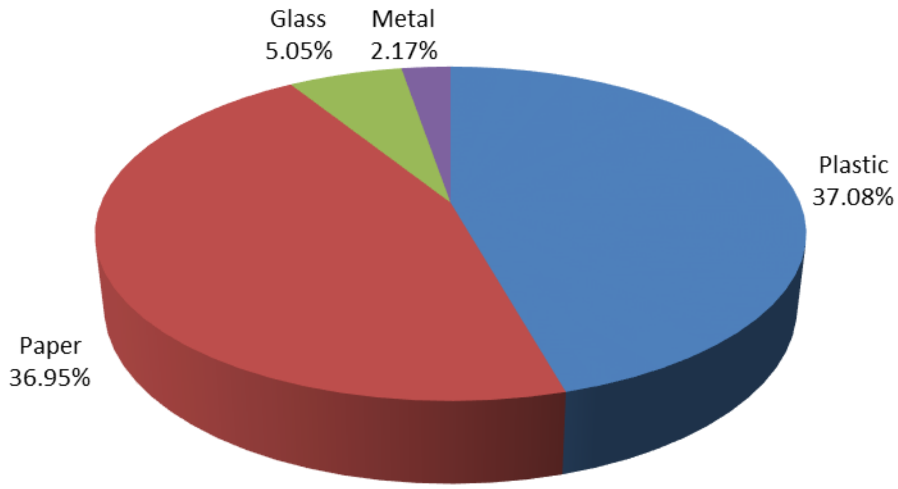


Figure 5: Percentage waste generated at Maseru City

*Waste handling and transactions within Maputsoe Urban Council (MUC)*

Unlike MCC, Maputsoe Urban Council (MUC) does not provide door to door services, but only focuses on collection of waste placed at the main roads. Due to lack of resources, the town clerk specified that MUC hires only one 4 tons truck each month to collect the waste from all the areas that MUC serve. Each month a different truck is hired as a way of making many people benefit from this job. These trucks are hired through government orders type of contract. The trucks are paid based on the millage they have covered which is 80 km per day on average and the payment is around M30, 000 a month. There are actually no specific collection points, the waste is collected at different areas just along the main road. The bins are only found in town and there are ten of them each with the capacity of 210 liters.

*Waste distribution and volumes produced within MTC*

Each and every week, about 23.3 tons of waste is disposed at Maputsoe dumpsite. The majority of this waste mainly comes from Garment sector which contributes about 14.3 tons of waste. (Figure 6) On the other side, households' contribution is almost insignificant since most of them burn their waste instead of taking it to the dumpsite. Diapers were identified as only households waste getting through to the dumpsite.

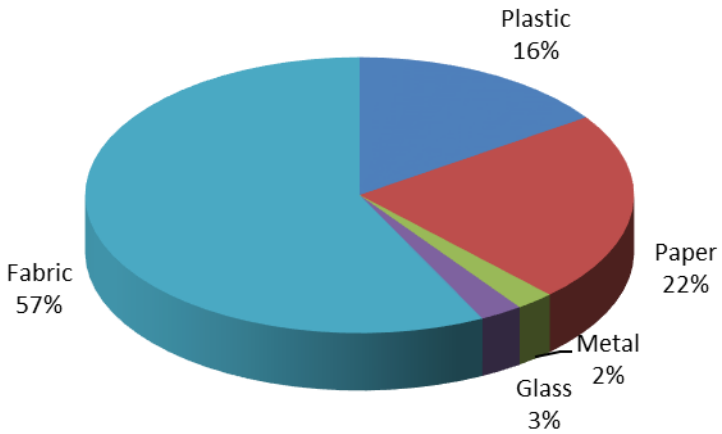


*Figure 6: Waste composition at dumpsite, Maputsoe*

# 8. Waste Handling and Development Manual for the two Municipalities

*The General Waste Management Proposal*

1. *Overview*

It is the intention of this section to provide clear background and guidelines for proper waste management in the context of Lesotho on the basis of the nature of waste as detailed in the preceding sections. The idea here is to move away, to the extent possible, from the idea of dumpsites to a situation where waste is made into useful products. The reality is that some forms of waste, such as filled children's diapers, are hard to handle and may not have an easy solution.

2. *Rationale for collection centres*

Separating the waste at or near its source is very important for reducing costs within an integrated waste management system, otherwise, unwanted materials which would rather remain at the source or transferred to the dumpsite would be co-collected. Therefore, primarily the approach will involve identifying several collection points within these municipalities. Currently both municipalities depend on one dumpsite each and that makes it hard for willing waste producers to transport it to distant places. Once the collection points are established the waste material can be taken directly from the source to the Collection Centre (CC) [which should be localised] for sorting and eventually directed to the Central Collection and Recycling Centre (CCRC) for final processing, packaging and shipping to the buyback centres or recyclers. (Figure 7).

3. *Number of Collection Centres*

For Maseru City Council the main objective is to have four collection centres, three (CC123) based on the extremities of the city and one (CC4) within the central Business District (CBD) around commercial places. CC123 will cater for individual households in the nearby villages and CC4 will cater for the nearby commercial places. For CC123, one can be along the Main North 1 road, another along the Main South 1 road and the last along the Thetsane road. The three main routes cater for huge populations in three faces of Maseru. Eventually both collection centres will feed the Central Collection and Recycling Centre. Similarly, for Maputsoe Town Council, two CCs can be established one base around villages surrounding Maputsoe town on both sides of the main road and the other one within the CBD.

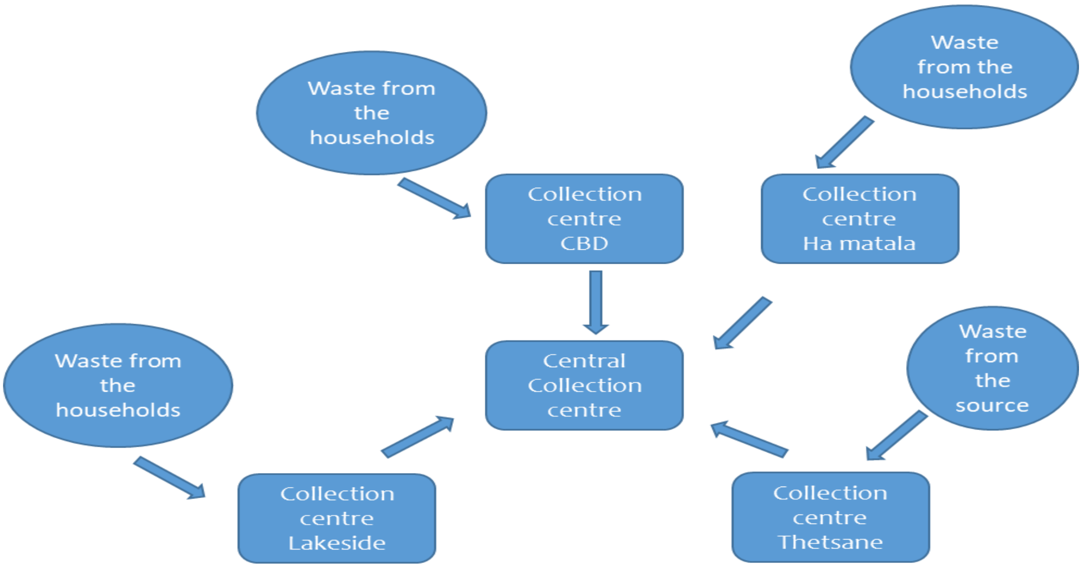


*Figure 7: Proposed Waste Management Plan within Maseru City Centre*

## 4. *The Nature of Collection Centres*

Literature studies reveal that a collection centre within residential areas may encourage the public to be involved in recycling activities since they will easily access the facility. Once the place for collection centre is identified, the first most important point to consider is fencing to prevent vandalism. At least part of the centre should have a shelter where workers can work on the project despite weather conditions. These provisions will ensure that operations taking place in that area are carried out under controlled environment. The centre will be the receiving point of waste from households and commercial places. At the centre, the waste will be sorted according to its various types such as paper, plastic or bottles to name a few. The reason for sorting at this point is to make sure that the CCRC does not have to handle unrelated waste since it is the key centre in the chain. After sorting the waste can be put into the skip that will be delivered to the CCRC for further processing.

5. *The nature of the Central Collection and Recycling Centre (CCRC)*

This point will be served by CCs. It is therefore going to be the main operation area and it is at this point where the processing plant is established. Wherever possible, the primary aim of the CCRC should be to add value by manufacturing full products out of waste. However, such things as crushing, bailing and sending waste to other recyclers in and outside the country can also be considered. It makes sense that CCRCs should be way large and better serviced with good infrastructure compared with the CCs.

6. *Waste Collection*

The plan is to employ the use of mini trucks to scavenge waste from different households and commercial places to the nearby CCs. The reason for using half- trucks is that they are fuel-efficient means of transport rather than the full-trucks. The trucks can either belong to the project or subcontracted. Then the waste from CC may be transported using full-trucks to a CCRC for further processing. In this case the full-trucks will have only one stop from collection centres to their final destination.

## *Target waste for recycling*

1. *How to handle textile waste*

**The nature of textile waste**

There are actually tons of textile wastes produced in both councils. The waste is actually composed of various materials with different fibre types. Understanding the nature of the textiles, what they are and their chemistry can make it easier to understand the suitable techniques to adopt during processing. This is because textiles are made from different materials and their nature at molecular level is eventually the influencing factor on the properties of the intended final product.

Some of the data informing the author's understanding of the textile waste was collected and analysed by the author in a report titled "The Preparation of a Detailed Inventory on Textile Discards by Textile Industry in Maputsoe, Lesotho,"[3] compiled for LNDC. Although the report does not cover the Maseru Municipality, it gives a picture of the nature of the mainly denim textile waste produced by Lesotho's textile industry. In that report, the textile waste was found to consist of a variety of fibres ranging from natural, synthetic and a mixture of both (Table 1). The report indicates that cotton, whether coming as pure or combined with other natural or synthetic fibres, takes the biggest pie of all forms of fabrics (Figure 8), followed by polyester fibres.

*Table 1: General description of the types of fabrics used by Maputsoe textile factories*

| ***Fabric*** | ***Description*** |
|---|---|
| **Cotton** | A natural fibre, made mainly of cellulose, that comes from the cotton plant. The fibre grows around the seeds of cotton plant. It is one of the most widely used fibres in the textiles industries. |
| **Polyester** | These are polymers that have one thing in common, an ester functional group, hence their name, polyester. Although some polyesters may have natural origin, we assumed that polyesters in this study are those of synthetic origin since they are the most widely used. Due to their durability properties, fibers spun from |

[3] Thimothy Thamae (2021), "The Preparation of a Detailed Inventory on Textile Discards by Textile Industry in Maputsoe, Lesotho," submitted to the Lesotho National Development Corporation.

| | |
|---|---|
| | polyester are favorite in textiles applications. |
| **Rayon** | A cellulosic fiber that is made from several sources of cellulose including wood and other plant materials. It is not considered a natural material because of the way it is processed. However, some people in the industry do not consider it synthetic either due to its natural sources. For the purposes of this study, we will consider it synthetic. |
| **Viscose** | It slightly differs from rayon in that its cellulose sources are never taken from Bamboo but rather, from wood and other plant fibers. Otherwise it is considered to be a form of rayon. |
| **Nylon** | It is not a single fiber with one chemical structure. Rather, it is a family of aliphatic or semi-aromatic polyamides that can be spun into fibers for textile applications. Nylons are synthetic fibers derived from thermoplastic polymers. |
| **Spandex, Lycra or Elastane** | At their basic structure, these fibers are a copolymer of polyether-and polyurea. They are known for their extensive elasticity. These three synthetic fibers are nearly the same thing structurally although they may differ cosmetically. They differ as a result of brand names and regional differences. We chose to report them as different fibers as reported on their use by different factories at Maputsoe. |
| **Twill** | This is not a specific form of basic fiber with a unique chemical structure. Rather, it is a form of weave that is used to make all kinds of fabrics. It is included in the list because it was identified as part of a composite making a list of fibers used in a fabric used by the factories. It's insignificant quantities in the mix does not introduce any appreciable error in the final results. |
| **Lock-knit** | Like Twill, is also not a specific fiber with a unique chemical structure. Rather, it is a fabric knitted with an interlocking stitch that resists pressure. It is treated |

| | |
|---|---|
| | separately for the same reasons given for Twill above. |

Identifying the waste types and their respectful quantities produced on monthly basis would help in knowing the nature of waste we are dealing with. Given this information it will be easier to develop the precise setup for this project.

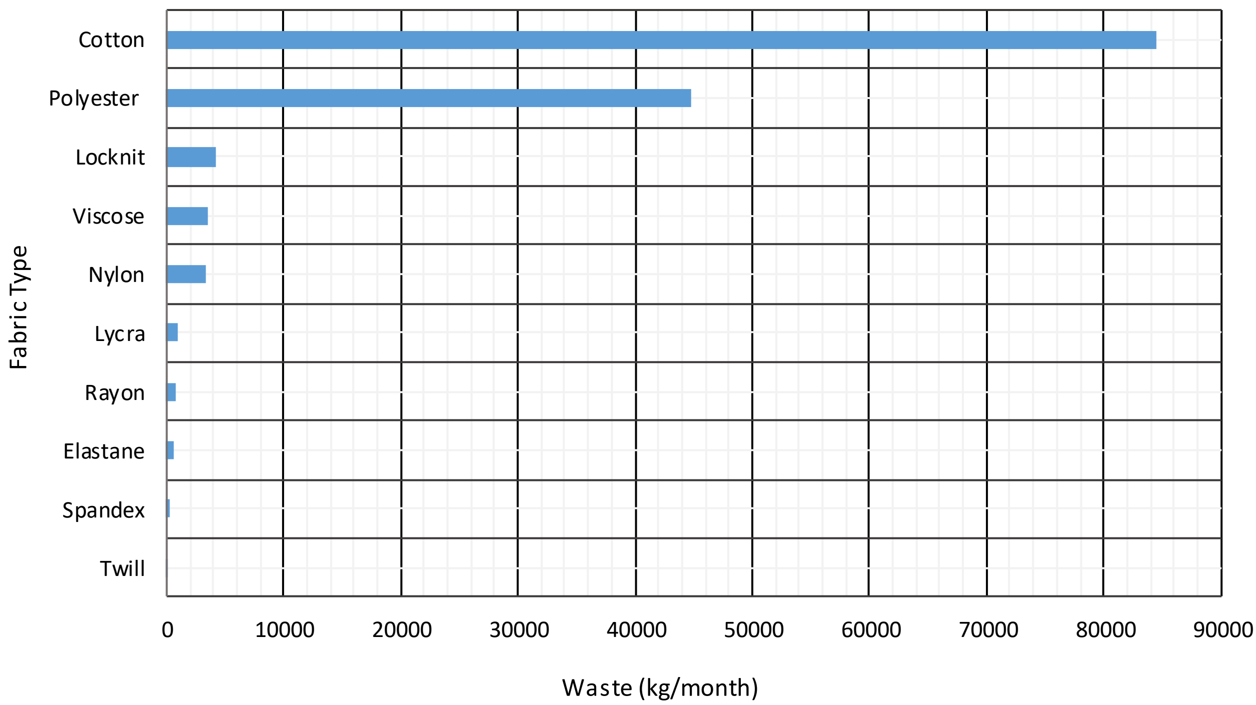


*Figure 8: Kinds and Amounts of waste fabrics produced my Maputsoe textile factories*

**The sorting process of textile waste**

Depending on the final use, the incoming textile waste will be separated and sorted according to colour or type of material. The advantages associated with colour sorting includes the fact that the final product may not need to be re-dyed, as a result this will not only save the energy but also eliminate the generation of pollutants that include dyes and fixing agents. More importantly the different fibre types or mixes of fibre types can also be sorted separately because the random mixture of different fibres can negatively affect the quality of some of the final products that many need to be made. Fortunately, it is easy to identify the type of waste, i.e. whether it is pure cotton, polyester, or a mixture thereof. Factory owners generally have that information as they also use it for labelling their products.

Use of manual sorting table can be selected for this process as it is inexpensive and, most importantly, it can also be easily maintained. It also encourages a labour intensive mode of operation and, therefore, can help in creating the much needed jobs. The aim is to go for conveyor sorting tables surrounded by a number of sorting personnel. Here the waste is simply placed on a sorting table and then pushed sorted into separating bins.

**Bailing and shipping textile waste**

After sorting process at the CCs, the waste can be pressed into bales at the CCRCs and shipped directly to waste recycling companies in South Africa. The author identified and visited one company (it appeared to be the only company in South Africa doing the textile waste recycling at a massive scale) in South Africa that is processing the waste in very large quantities and imports waste from as far as Brazil. Baled waste can be sent to such companies for profit.

In order to maximise the profits it is always important to find a good baling machine that can be able to maximize the tonnage per trip to the recycler. Baling machines are versatile as they come with different sizes and capacities. Choosing the right size is very important. This can actually contribute as an advantage to a transportation cost savings from a lower transportation cost per ton. For this project we are recommending a bailing machine with at least 200 ton pressing capacity. This is the best capacity to maximise the load per trip. Even though these types of baling machines are expensive, they ensure profit in the long run.

As it is indicated before, proper sorting is often seen as fundamental. Waste should be collected and then sorted according to its type of fibre. The sorting process is very important because this actually determines the selling price. The effective sorting results into a healthier selling price when waste is sold to the recycler.

**Processing of textile waste**

After an efficient sorting, the textile waste material can also be processed into variety of products as opposed to shipping it to other countries. Given the composition of the feed material the waste can be used as filling or processed into variety of non-woven products. The studies reveal that the kind of waste we are dealing with is mainly heterogeneous in nature. Therefore, it is more feasible if the waste can be processed to produce filler or non-woven products.

Both filler and nonwoven products require fibre recovery from the waste. This is the first and crucial stage of textile recycling. At this point the fibre is recovered through disintegration of the textile offcuts into loose fibres. The process occurs through mechanical action of a series of a high speed cylinders covered with steel pins. After the process the fibres can either be used as filling for pillows, sofas and mattresses or processed further to produce non-woven materials.

Common applications of non-wovens include products such as felt, blankets, electric cabling, and insulation as well. As per ASTM international standards (The American Society for Testing and Materials) non-woven material is defined as “a textile structure produced by bonding or interlocking of fibres or both, accomplished by mechanical, chemical, thermal, or solvent means, and combinations thereof”. For this kind of production, the selection of fibre is very important and proper selection can actually result into a good quality end product. The frequently used fibres comprise of some natural fibres such as cotton and synthetic fibres such as polyester and rayon. The advantage is that the majority of waste produced in our textile firms was found to consist mainly of the combination of cotton and polyester.

2. *How to handle plastic waste*

**The nature of plastic waste**

Plastics are often manmade materials that usually use polymers as main ingredient. Due to their plastic (moldable) nature, plastics may be shaped, extruded or even pressed into different products. The plastic structure is mainly made of organic polymers. These polymers usually contain carbon atom linked with either nitrogen, oxygen or sulfur. Single structures repeat itself to form a large chain of a molecule called polymer and the repeating structure is called a monomer. The monomer is the one that defines important properties of the plastic.

The different monomers result in different classification of plastic. They may be grouped into acrylics, polyesters, silicones, polyurethanes and halogenated plastics.

They come into two types: Thermoplastics and thermosets. Thermoplastics are those which, when heated, do not change their chemical structures. SO they can be heated and molded into new products over and over again. For thermosets, once they have solidified shape, they may not melt again, but instead they decompose. Example of common thermoplastics include: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS) and Polyvinyl Chloride (PVC). Some common thermosets include polyurethane (PU), some polyesters, epoxies and some silicones.

Pure plastics are less toxic because they are not soluble in water and they get hardly consumed by micro-organisms. But plastics may contain different additives which may be toxic. The additive may be plasticizers that are added to improve the plastic properties. Some of these toxic additives may leach out to the environment when exposed to certain temperatures, releasing some toxic pollutants. That is why uncontrolled plastic burning may be dangerous.

**Waste plastic recycling**

Plastic recycling is one of safe waste management measure that could be taken. Although some thermosetting plastics can be noted on the waste in both Ha Tšosane and Mokotakoti dumpsite, thermoplastics are almost always the most common and the target of waste pickers due to their recyclability. CCRCs can bail plastics as they are and ship them to recyclers, add value by shredding (Figure 9) the plastics and send them to recyclers or, better still, recycle the plastics themselves.

There are few companies in South Africa that buy grinded or shredded plastic waste. One of them is KM Plastics, based in Kwazulu-Natal. They accept variety of plastic types including HDPE, PS, PP and flexible PVC such as electrical cables. KM Plastics simply processes plastic waste to plastic resins, they do not produce products. Rather they sell the resins to manufactures. The other one is Mpact Limited. It does the actual processing of plastic waste into packaging products. There is also the one called ALPLA. This one only specializes in processing polyethylene plastic into packaging products.

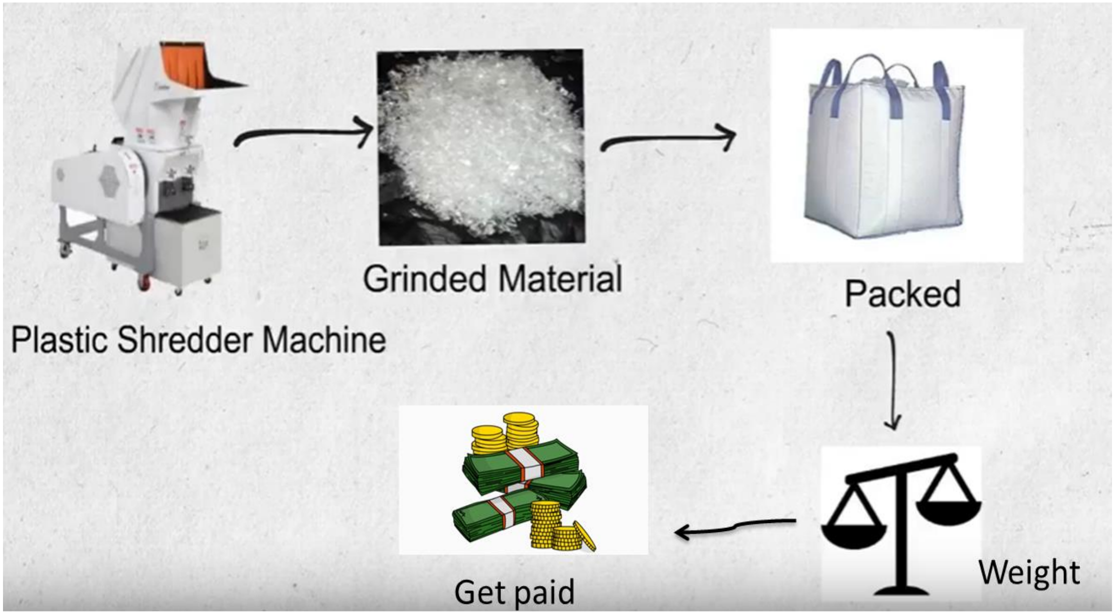


*Figure 9: Selling of Shredded Plastic*

The most efficient way to recycle plastic is through the use of extruders and injection molders to make new common household products. Plastic waste can also be used in artisan pursuits such as making hand bags, pencil cases, decorative light bulbs, flower pots and so on (Figure 10) although such pursuits do not call for production in volumes and do not use up significant quantities of waste.

*Figure 10: Artistic plastic products*

**Thermoplastic waste processing**

This is a high volume manufacturing process in which plastic (shredded, pellets or powder) is melted into a resin and then forced through a die. The extrusion process is outlined in Figure 11. Plastic, together with colorants or additives, are added into a hopper, the mix pass through the barrel where it gets heated to the melting temperature of the plastic. The molten plastic undergoes mixing with colourants and additives which is the primary aim of the extrusion process. The end-result can be either flat panels that pass through a die as final products or pellets that will later be shredded and put into an inject molder. In this case, the now hardened plastics is melted again into an extruder-like machine called injection molder whose purpose is not longer to mix but to inject with force, molten plastic into molds to make final products.

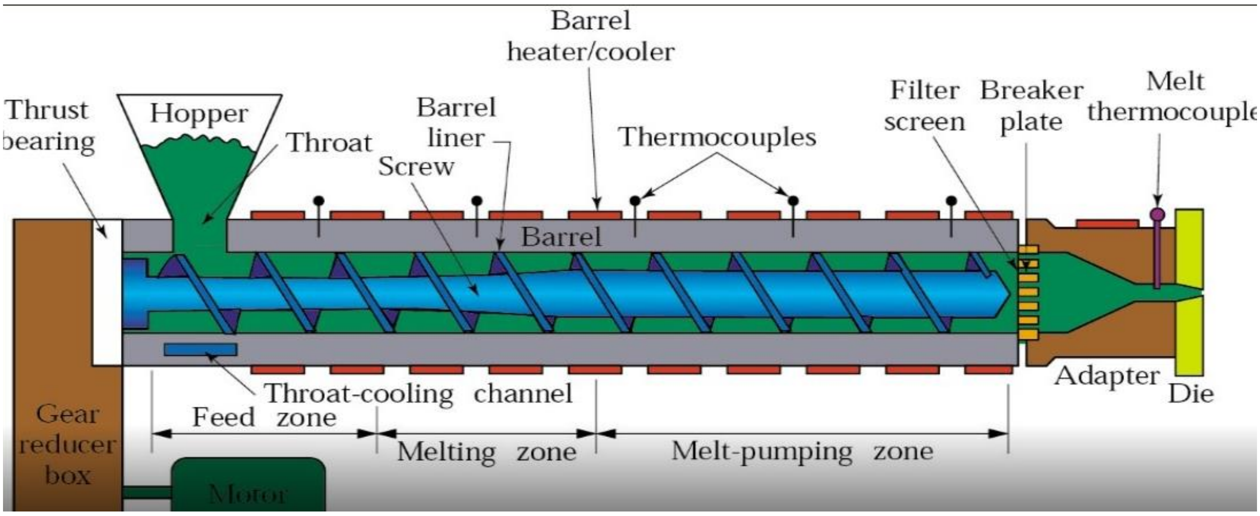


*Figure 11: Plastic Extrusion*[4]

Extruded and/or injection molded materials have a wide range of applications including pipes, tiles or sheets, beams, lumber, garbage cans, fence, furniture such as bench and many others.

3. *How to handle paper waste*

**The nature of waste paper**

Waste paper is ubiquitous in Lesotho. Vast amounts are produced every day. It comes in different forms including cardboard boxes, cartons, newspapers and office papers. It is not a surprise then, that paper recycling (Figure 12) is one of the most common practices among others. It is so prevalent that one would find at least one buy-back centres in Maseru most neighborhoods. Office paper and cardboard boxes are the most commonly collected and pressed and sold to recycling companies in South Africa. In nature paper is thin sheet produced from cellulose fibers that are extracted from wood and other

[4] Ranjan, S. Plastic Extrusion Process, March 11, 2018, Lincolnplastic.com.

lignocellulosic materials such cotton, rice or wheat straw. These fibers are pressed together chemically and/or mechanically to fuse and form a strong solid.

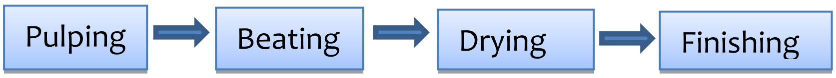


*Figure 12: Production process of paper*

**Waste paper recycling**

Paper recycling can be approached in various ways. It can just be sorted and pressed into bales, then sold to paper recyclers in South Africa. The portion of the other paper can be used to produce paper based furniture and some decorative products. The author and his research assistants have experimented with the making of waste paper furniture, moving beyond the proof of concept. The furniture is made from the used waste cardboard boxes, waste newspapers and the National University of Lesotho developed binding mixture called c-binder. This product is a completely new concept and may not be found anywhere in the world.

The products made of this furniture material may range from modern television stands, coffee tables, vases and beds (Figure 13). The project, if carried out in large scale, has a potential to open a chain of jobs, ranging from waste collection, product manufacturing and product distribution. Most importantly is that it does not require any expensive machinery to carry it out and it uses mainly locally available raw materials.

*Figure 13: Various kinds of paper furniture*

# 9. Policy Recommendations

Almost all of waste that reaches the dumpsites in one version or the other can be recycled or reused. However, one of the most stubborn waste problems facing our dumpsites today is the appearance of babies' diapers as part of the waste. By their nature, and they fact that they come filled with babies' waste, this sort of waste is both hard to handle or recycle. It is recommended that the government looks into the possibility of legislation to encourage the use of biodegradable diapers.

# 10. Conclusions

The two biggest dumpsites in Lesotho are found in the city of Maseru (Ha Tšosane) and Maputsoe (Mokotakoti). The situation of open burning of waste in these two municipalities presents a danger. Just a year ago, the people in areas surrounding Ha Tšosane had to endure weeks of continued emission of smoke from an apparently spontaneous fire which erupted within the dumpsite and proved hard to put off.

In this report, we observed the nature of the dumpsites in the two municipalities and assessed it though a limited Life Cycle Assessment tool. We then recommended the best way to rearrange the collection procedures to make recycling rather than the dumping of waste easier. Specific and abundant materials observed in the dumpsites were analyzed for their potential use in simple recycling methods. We also recommended the implementation of a specific policy to control the dumping of diapers which are hard to recycle and present a potential time-bomb for the already stressed dumpsites.

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# 12. Annexure: Waste Management Plan

**THE PLANNING PHASE**

**Setting Objectives and targets**

The study on promotion of BAT/BEP to reduce U-Pops release from waste open burning in Lesotho [8], showed weak system on solid waste management in Maputsoe and Maseru City councils. The population served is very small, resulting in high open dumping and burning of waste. Even for collected waste, most of it remains in dumping sites, becoming nuisance on the environment. This creates a need for a much more practical Environmental Management Plan.

In this waste management plan, clear objectives are set for the city of Maser and the town of Maputsoe (see Table 1) with their corresponding input resources, and expected results. Each objective is prioritized by matter of urgency and affordability. In order to achieve the set goals, different waste management scenarios were anticipated (Figure 1 and Figure 2) and the affordable one is selected for implementation.

*Table 1: Objectives with necessary inputs and expected outputs*

| Objective | Target and its quantifiable value to be reached | Target Inputs (necessary resources) | Target Outputs (expected results) | Responsible Party and/or Stakeholder | Milestones and applicable Deadlines | Priority (High, Medium, or Low) |
|---|---|---|---|---|---|---|
| Prevention of illegal dumping and open burning of waste | 1. Increase capacity of waste collection | -Purchase of additional skips and waste bins<br><br>-Funding required | Most of waste will be collected from source (households, commercial places, schools, factories,) to pick up spot | City/ Town council, Village Residents, Commercial outlets, Schools, Factories | 31st December 2021 | High |
| Improve waste collection systems | 2. Set up collection centres (CCs) and central collection and recycling centre (CCRC) | Mini trucks, skip trucks, warehouses and/ or factory shells | All the waste collected at the pickup spots will be transported to the CC. The waste will further be collected from CCs to CCCs | City/ Town Council/ Private companies | By 31st December 2021 | High |
| Increase recycling and recovery rate of waste | Set up sorting systems at the CCs | Sorting tables, skip truck, skips, and unskilled laborers.<br><br>Funding required | Sorted waste transported to CCC | City/ Town council or private company | 31st January 2022 | High |
| | | | | | | |

| Objective | Target and its quantifiable value to be reached | Target Inputs (necessary resources) | Target Outputs (expected results) | Responsible Party and/or Stakeholder | Milestones and applicable Deadlines | Priority (High, Medium, or Low) |
|---|---|---|---|---|---|---|
| | Waste recycling, up-Recycling and packaging | Purchase of processing machines, unskilled laborers,<br><br>Funding required | Re-cycled and up-cycled products.<br><br>Packaged waste for resale. | City/ Town Council or private company | 31st January 2022 | High |
| | Sourcing market for processed waste | Marketing office at CCC.<br><br>Marketing and Sales team | Creation of revenue from production or selling | City/ Town or private company | 28th February 2022 | High |

## SCENARIO CREATION

### Description of scenarios

The data that was collected from the preliminary stage of this project revealed that the total waste that is generated at both municipalities per week is 276.5 tonnes. This is the data that was used to develop the scenarios of the waste management at the two selected municipalities. Therefore the material flows of the scenarios are assumed to occur on weekly basis. The assumptions, especially in terms of numbers, given in the scenarios are based on what appears possible to the investigators. They should not be seen as absolute as they are mainly meant to be indicative.

### Scenario 1: High collection rate, high baling rate, no recycling/up-cycling

In scenario 1 it is assumed that there is high collection rate and high packaging rate without recycling and up-cycling of waste. It is assumed that, 20% of the total waste generated will not be collected by the proposed recycling system, resulting in open burning and illegal dumping to a total of 55.3 tonnes. The 20% value is based on a reasonable assumption that some the system in all its facets, including people and institutions, will not be ready to collect all waste in the beginning even with the best of intentions.

From collection to waste sorting and processing stages, it is assumed that there will also be a 5% of the collected waste that will result into residue (11.1 tonnes) which will be either be incinerated or disposed at dumpsites. Processing of waste always leads to some parts of it being thrown away as a by-product for various reasons. The processed waste (210.1 tonnes) which constitutes about 76% of the total waste generated will simply be packaged or shredded at the CCRCs and shipped to South Africa. This scenario is illustrated in Figure 1 of this appendix.

**Scenario 2: High collection and baling rates, medium recycling/up-cycling rate**

In scenario 2, it is assumed that there is high collection and baling rates and medium recycling rate. The collection rate is still assumed to be the same as in scenario 1 at 20% (estimated at 55.3 tonnes).

Moving on to sorting and processing, it was assumed that 10% of the collected waste will result into residue to be incinerated or dumped. This value is higher than that of scenario 1 because scenario 2 involves more processes than scenario 1 hence resulting into more residue generation estimated at 22.1 tonnes.

At the processing stage, it is assumed that 20% of the collected waste will undergo recycling/up-cycling process (39.2 tonnes) and the rest will be baled and shredded (159.3 tonnes) then shipped to South Africa. The total waste that will be processed is 199.1 tonnes which constitutes 72% of the waste generated as illustrated in Figure 2.

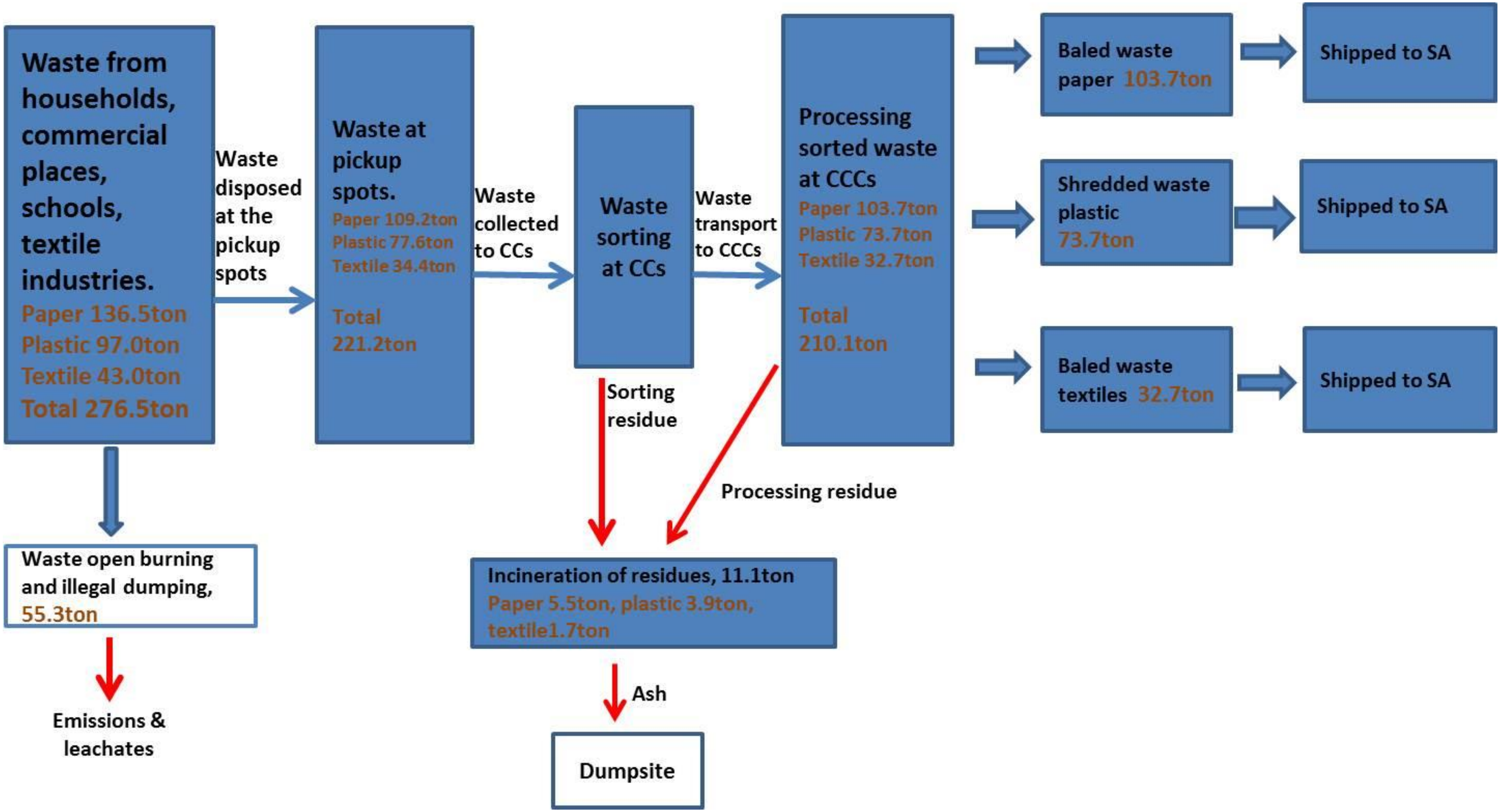


Figure 1: Scenario 1, material flow for waste management at Maseru and Maputsoe

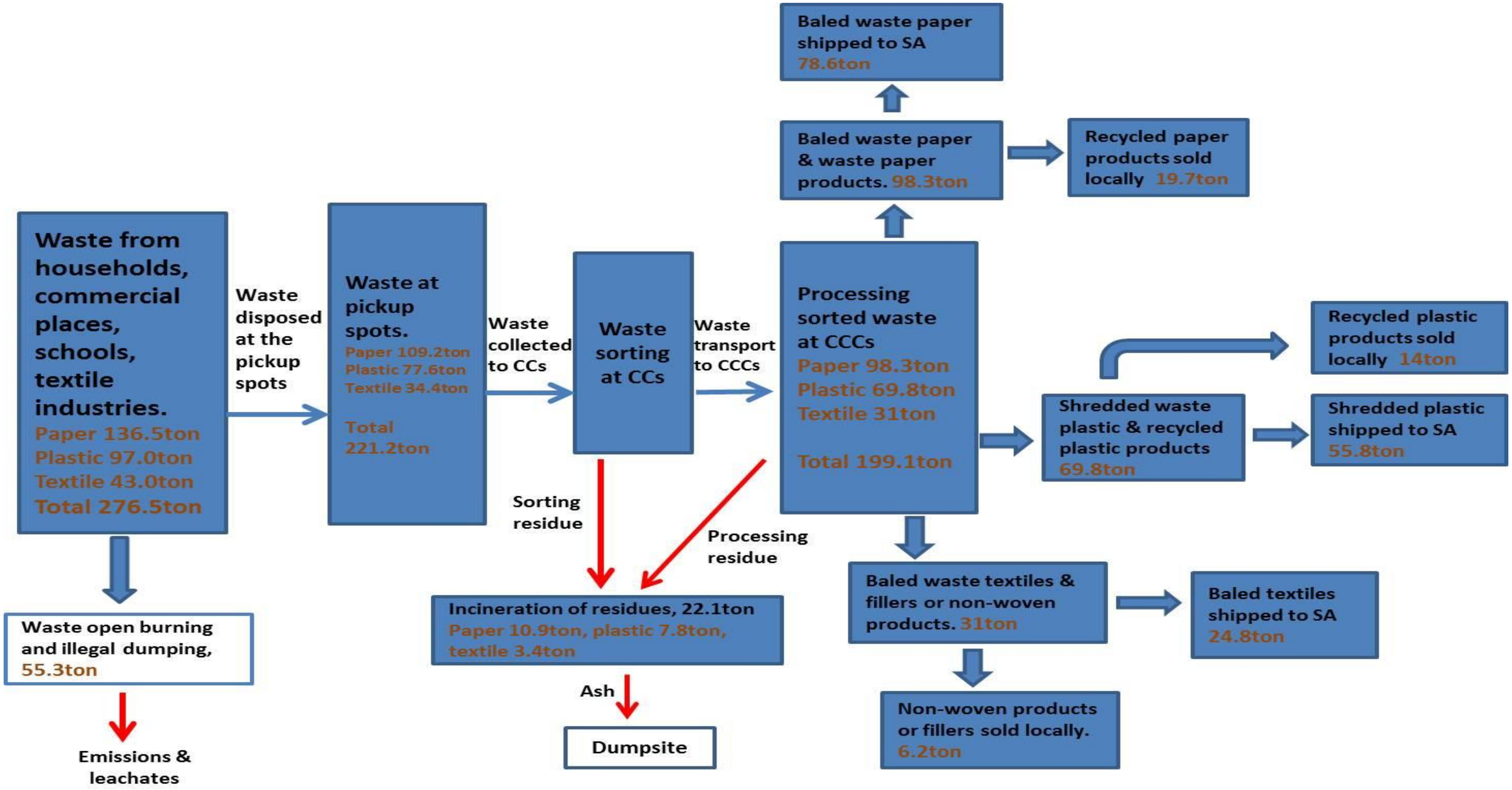


Figure 2: Scenario 2, material flow for waste management at Maseru and Maputsoe

**Cost comparison of scenarios**

When comparing the two scenarios, it is observed that the scenarios are similar from waste collection to waste sorting stage at the CCs. Therefore the main difference is at the processing stage which takes place at the CCRCs.

***Cost of scenario 1***

In scenario 1, the processing of waste only involves packaging and shredding of waste then shipping the waste to South Africa. For this reason, the machinery needed is a plastic shredder and baling machine and also an incinerator. Although there are two types of waste that will be baled, one baling machine can be used periodically for both types of waste. This decision will also lower the capital needed as compared to purchasing two baling machines. The total estimated amount of funding needed for equipment and machinery in this scenario is M4,883,165.00 (Table 2).

*Table 2: Machinery and equipment needed for scenario 1*

| Machine Type | Types of waste | Product | Quantity | Total Cost (M) |
|---|---|---|---:|---:|
| Sorting table | All waste | sorted waste | 25 | 84,125.00 |
| Baling machine | All waste | waste bales | 2 | 410,040.00 |
| Plastic shredder | Plastic | shredded plastic | 2 | 441,000.00 |
| Waste incinerator | All waste | ash | 2 | 1,848,000.00 |
| Skip truck | All waste | sorted waste | 3 | 1,500,000.00 |
| Mini truck | All waste | mixed waste | 6 | 600,000.00 |
| **Total** | | | | 4,883,165.00 |

**Cost of scenario 2**

In scenario 2, the processing of waste involves packaging and shredding of waste then shipping the waste to South Africa as well as recycling the waste and selling the end products locally. Therefore in this scenario, additional machinery and equipment is needed for recycling and up-cycling operations hence the funding needed for scenario is M28,461,284.40 (Table 3).

*Table 3: Machinery and equipment needed for scenario 2*

| **Machine Type** | **Types of waste** | **Product** | **Quantity** | **Total Cost (M)** |
|---|---|---|---|---|
| Sorting table | All waste | sorted waste | 25 | 84,125.00 |
| Baling machine | All waste | Waste bales | 2 | 410,040.00 |
| Rag tearing machine | textile | torn textile | 2 | 273,839.40 |
| Non-woven machine | textile | Non-woven fibre | 2 | 22,589,280.00 |
| Plastic shredder | plastic | shredded plastic | 2 | 441,000.00 |
| Plastic extruder | plastic | plastic bar, wire, granules, sheet, pipe | 2 | 615,000.00 |
| Waste incinerator | All waste | ash | 2 | 1,848,000.00 |
| Paper processing equipment | paper | paper furniture, vases | various | 100,000.00 |
| Skip truck | All waste | sorted waste | 3 | 1,500,000.00 |
| Mini truck | All waste | mixed waste | 6 | 600,000.00 |
| **Total** | | | | 28,461,284.40 |

**Overall comparison of scenarios and scenario selection**

*Table 4: Comparison of scenarios*

| | ***Scenario 1*** | **Scenario 2** |
|---|---|---|
| Description | • Increased rate of waste collection to 79.9%<br>• Highest rate of waste packaging 76.3%<br>• Zero rate of waste recycling and up-cycling | • Increased rate of waste collection to 79.9%<br>• High rate of waste packaging but lower compared to scenario 55%<br>• Medium rate of waste recycling and up-cycling, 18.1% |

| | | |
|---|---|---|
| | • Low rate of residue generation, 5% | • Doubled rate of residue/ash generation, 10%, compared to scenario 1. |
| ***Material flow / physical impacts*** | | |
| | • High reduction of waste burned and illegally dumped<br>• High positive impact on public health and urban environment | • High reduction of waste burned and illegally dumped<br>• High positive impact on public health and urban environment |
| **Financial impacts** | | |
| | • Medium increase of costs | • High increase of costs |
| **Stakeholders:** | | |
| Council | • Medium financial risk<br>• Achieve the goal of better health and environment conditions | • High financial risk<br>• Achieve the goal of better health and environment conditions |
| Communities | • Better health and environmental standards as desired<br>• Offer of few new jobs | • Better health and environmental standards as desired<br>• Offer of higher number of new jobs |

**Verdict**

It is best to select scenario 1 because it will be less costly to start in the beginning of the project. Although scenario 2 will offer more jobs than scenario 1, there is a higher amount of waste that is produced as by-products than in scenario 1. The emphasis of this project is more on a more efficient waste management system than on job creation. Additionally, scenario 2 requires enormous amounts of funding for equipment and machinery and operations costs might take the figure higher. Scenario 2 should rather be a future plan that will be introduced gradually.

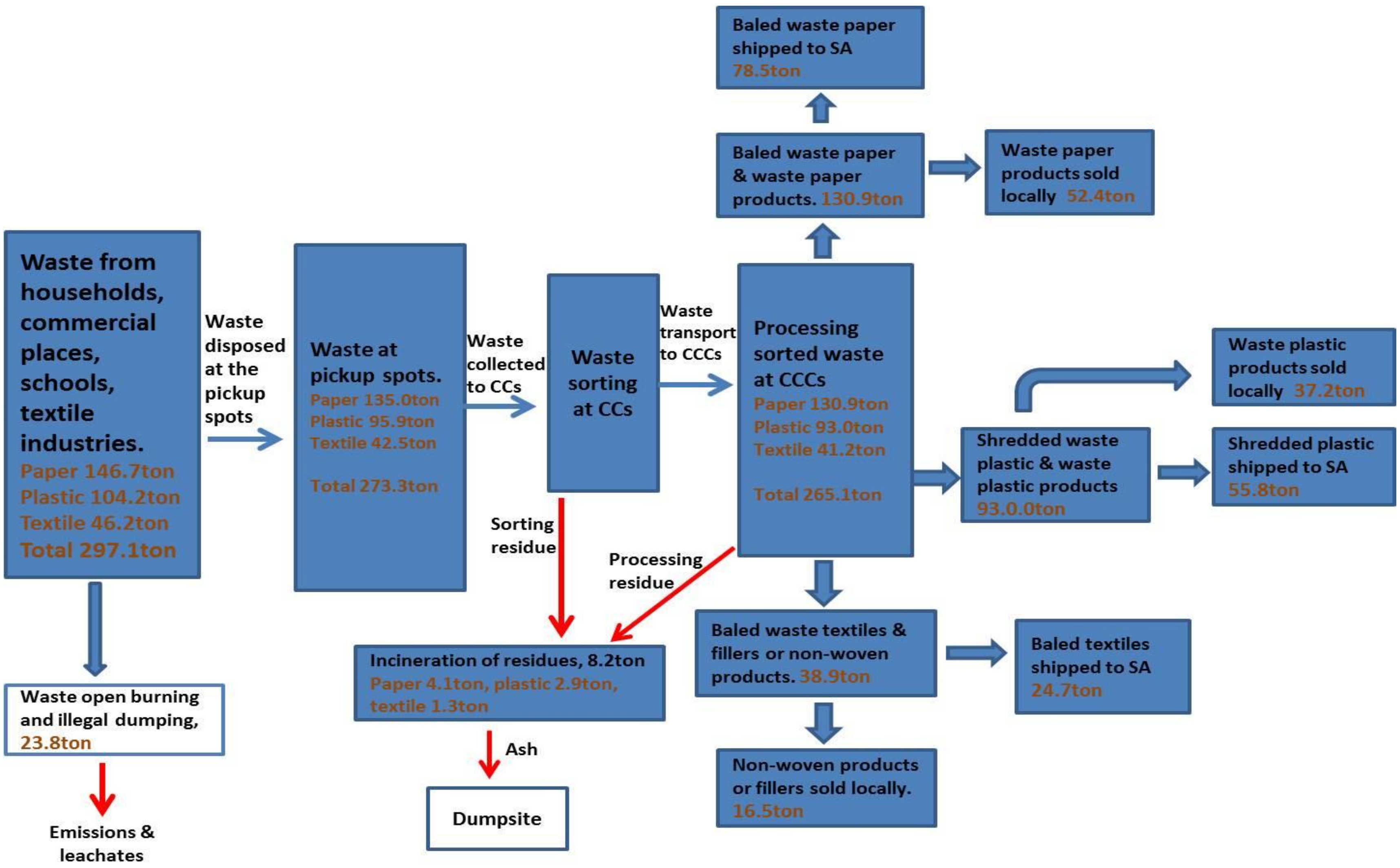


*Figure 3: Material flow of the improved system*

**PREDICTED MATERIAL FLOW BASED WASTE MANAGEMENT SYSTEM IMPROVEMENTS**

According to World Bank Data, the rate of annual population in Lesotho is 0.8%. [12] Assuming the amount of waste generated will increase by the same rate and it stays constant over a period of 10 years, the waste generated will be increase to 297.1 tonnes per week in the tenth year. The improved WMS is an anticipation or assumption of the level of the WMS after 10 years. Therefore in improved WMS there will be an increase on the waste collection rate resulting into reduced rate of waste illegal dumping and open burning. The other improvement is the increase on waste recycling and up-cycling rate. This factor will generate more revenue and provide more jobs for communities at the same time achieving health and environmental standards. The improved system material flow is shown in Figure 3 and the summary of changes from the current WMS to improved WMS shown in Table 5.

*Table 5: Summary of changes from the current WMS to the improved WMS*

| **Process/Flow** | **Present system** | **Future/Improved system** |
|---|---|---|
| Waste Generation | Most of the waste generated is openly burned or illegally dumped. MCC can only serve 35% of Maseru City. MUC does not even offer door to door services | The waste collection rate in the improved system is increased to 92%. There is a proper facility (CCs) for sorting of waste. |
| Collected Waste | 100% of the collected waste is going directly to the dumpsite | The entire collected waste is going to CCs for sorting and later to CCCs for processing. Only the residues are incinerated and dumped. |
| Uncollected Waste | Open burning and illegal dumping | Open burning and illegal dumping of waste are |

| Process/Flow | Present system | Future/Improved system |
|---|---|---|
| | | reduced to 8%. |
| Materials Recovery Facility | There is only an informal and inefficient sorting at the dumpsite | In the improved system there is packaging and shredding, recycling and up-cycling activities of waste at the CCCs. |

**ACTION PLAN**

To achieve the set of objectives, actions to be taken were pointed and these are summarized in Table 6. Some actions are expected to be taken in year 1 to 3 of implementation phase, others in year 3 to 5, while others in 5 to 10 years.

*Table 6: Action plan for reaching determined targets of the overall SWMP*

| Action Plan for Period [2021- 2031] | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Objective** | **Target Number with Brief Description** | **Responsible Party and/or Stakeholder** | **Actions to be Taken** | | |
| | | | | **Short-term (1-3 years)** | **Mid-term (3-5 years)** | **Long-term (5-10 years)** |
| Municipal Solid waste | Prevention of illegal dumping and open burning of waste | 1. Increase capacity of waste collection | City/ Town council Village Residents, commercial institutes, schools, factories | ○ Hold awareness seminars whereby communities will be educated about waste, outcome of burning it and | ○ Awareness seminars should be continually held:<br>○ More trucks will be | Awareness seminars should be continually held |

| Action Plan for Period [2021- 2031] | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Objective** | **Target Number with Brief Description** | **Responsible Party and/or Stakeholder** | **Actions to be Taken** | | |
| | | | | **Short-term (1-3 years)** | **Mid-term (3-5 years)** | **Long-term (5-10 years)** |
| | | | | importance of recycling it:<br><br>○ A number of waste drums will be provided for each village for villagers to discard their waste.<br><br>○ Mini trucks will be bought, these trucks will be used to scavenge waste from provided waste drums within villages to CCs | bought to satisfying the increasing population | |
| | Improve waste collection systems | 2. Set up collection centers and central collection and recycling center | City/Town Council/ Private companies | ○ Four CCs will be set up, along Main South 1, Main North 1, Kofi-Anan Road and the other in town. | | |

| Action Plan for Period [2021- 2031] | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Objective** | **Target Number with Brief Description** | **Responsible Party and/or Stakeholder** | **Actions to be Taken** | | |
| | | | | **Short-term (1-3 years)** | **Mid-term (3-5 years)** | **Long-term (5-10 years)** |
| | | | | ○ Then location for CCRC will be spotted.<br>○ The CCs and CCRC will be fenced, then shelters will be constructed within each center | | |
| | Increase recycling and recovery rate of waste | Set up sorting systems at the collection centers | City/Town council or private company | ○ Purchase of Sorting tables for CC<br><br>○ Hiring of casual laborers and manager or supervisor | | |
| | | Waste recycling, up-cycling and packaging | City/Town Council or private company | ○ Purchase of waste processing and packaging equipment<br>○ Causal Laborers and manager/supervisor will be hired for CCRC operation activities | | |
| | | Sourcing market | City/Town Council | ○ Hiring of sales and | | |

| Action Plan for Period [2021- 2031] | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Objective** | **Target Number with Brief Description** | **Responsible Party and/or Stakeholder** | **Actions to be Taken** | | |
| | | | | **Short-term (1-3 years)** | **Mid-term (3-5 years)** | **Long-term (5-10 years)** |
| | | for processed waste | or private company | marketing team | | |
| | | Waste collection vehicles | City/Town Council or private company | ○ Purchase of additional waste collection vehicles | | |

**IMPLEMENTATION**

**Implementation program**

For action plan to be effectively executed, implementation program was established (Table 7). In this program, for each action to be taken, relevant policy and legal instruments needed are stated, together with relevant stakeholder participation and public awareness efforts necessary.

*Table 7: Planned implementation program to ensure effective execution of the plan's actions to be taken*

| Implementation Program | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Actions to be taken** | **Costs of actions** | **Economic Instruments to cover costs of each action** | **Relevant Policy and Legal Instruments** | **Relevant Partnerships and Environmental Agreements to be forged** | **Relevant Stakeholder Participation and Public Awareness efforts** |
| Municipal Solid Waste | Educate the public about waste in general | *Low* | City/Town Council | *Ban opening burning of waste and improper dumping of waste fines for littering* | | *Waste awareness seminars with the public by* City/Town Council |
| | Purchase of Waste Drums, skips, mini trucks, skips trucks and other waste collection vehicle | *High* | City/Town Council | *Standards for waste collection equipment and vehicles* | *PPP with companies already having waste collection vehicles* | |
| | *Construction of* | *High* | City/Town | City/Town | *Privatization-* | *Mass* |

| Implementation Program | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Actions to be taken** | **Costs of actions** | **Economic Instruments to cover costs of each action** | **Relevant Policy and Legal Instruments** | **Relevant Partnerships and Environmental Agreements to be forged** | **Relevant Stakeholder Participation and Public Awareness efforts** |
| | *CCs and CCRC facilities and fencing* | | Council | Council building standards | City/Town Council *may use private companies to facilitate construction projects* | *advertisement and educational activities for the public to understand the activities of the facilities and how they can get involved.* |
| | *Purchase of sorting tables, press, packaging and waste processing machines* | *Medium* | City/Town Council | | *Joint Ventures with waste experts* | |
| | *Hiring of casual laborers and managers or* | *Medium* | *Monthly collection fees and revenue* | *Local labor codes* | | *Use of public recruitment platforms such* |

| Implementation Program | | | | | | |
|---|---|---|---|---|---|---|
| **Waste Type** | **Actions to be taken** | **Costs of actions** | **Economic Instruments to cover costs of each action** | **Relevant Policy and Legal Instruments** | **Relevant Partnerships and Environmental Agreements to be forged** | **Relevant Stakeholder Participation and Public Awareness efforts** |
| | *supervisors* | | *from operation of CCRC* | | | *as newspapers and radios* |

## MONITORING AND REVIEW

Monitoring and review section states the actions to be monitored (Table 8) in order to evaluate the progress of the implemented plan. In evaluation, the responsible party will check if the plan remains effective and relevant and make necessary adjustment when there is a need.

### Actions to be monitored

*Table 8: Actions to be continually monitored as part of the new waste management system*

| Area of waste management | Actions to be monitored | Responsible party or stakeholder |
|---|---|---|
| General | Volume of collected waste and its composition | CCs and CCRC management |
| | Environmental and health outcomes related to waste management | City/Town Council |
| | Complaints of general public | Village communities and CCs |
| | | |
| Collection and Transportation | Revenues generated from waste collection service | City/Town Council / engaged private company |
| | Operational expenses for collection service | City/Town Council / engaged private company |
| | Ratio of covered population to overall population in served areas | City/Town Council / engaged private company |
| | | |
| | Number of mini trucks used to scavenge waste | CCs and CCRC management |

| Area of waste management | Actions to be monitored | Responsible party or stakeholder |
|---|---|---|
| Recycling and Recovery | in each region and volume of waste collected monthly | |
| | Volume of waste recycled and packaged for resale | CCRC management |
| | Revenue generated from up-cycled or recycled products<br>Revenue generated from sold packaged waste | CCRC management |
| | | |
| *Disposal* | Volume of waste entering the disposal sites | City/Town Council |
| | Illegal dumping and burning rate at disposal sites | City/Town Council |
| | Leachate content and emission level from dumped waste and open burning | City/Town Council |

**Performance indicators**

The performance indicators (PI) help to monitor the system by quantifying the results or performance of implemented waste management plan. In every 3 years, the performance report will be published and a review of the system will occur.

Targets linked to PI were calculated from the initial percentage of scenario to be implemented (Table 9). Then performance was estimated to increase or decrease by minimum of 3% every year. The collection and processing/packaging rates are estimated to be 80% and 76% respectively in year 1. 20% is predicted to be uncollected waste, which is expected to decrease to 17.7% in year 5. The disposal rate is estimated to be 4% of the total waste generated and 5% of the collected waste.

*Table 9: Performance indicators for assessing performance outputs of the new WMS based on implementation of the SWMP*

| Area of waste management | Performance Indicator (PI)[5] | Targets linked to PI | Necessary data collection[6] | Responsible party for data collection |
|---|---|---|---|---|
| General | *Increase in Waste collection rate (%)* | *80.0, 82.4, 84.9, 87.4, 90.0* | *Quantity of waste collected by each CC* | *CCs and CCRC management* |
| | | | | |
| Collection and Transportation | *Increase in Waste collection rate (%)* | *80.0, 82.4, 84.9, 87.4, 90.0* | *Number of mini trucks used to scavenge waste in each region and* | CCRC/ City/Town Council/ *engaged private company* |

[5]Performance indicators have the purpose of quantifying the performance outputs of the overall system. As such, the performance indicators selected to assess the plan will be closely linked to the targets determined to meet plan objectives.

[6]Should be closely related to the actions to be monitored.

| Area of waste management | Performance Indicator (PI)[5] | Targets linked to PI | Necessary data collection[6] | Responsible party for data collection |
|---|---|---|---|---|
| | | | *volume of waste collected* | |
| | *Cost recovery rate (%)* | 20 | *Revenues generated from waste collection service against Operational expenses for collection service* | CCRC, City/Town Council |
| | *Collection coverage rate (%)* | *35, 36, 37, 38.1, 39.2* | *Ratio of covered population to overall population in served areas* | City/Town Council |
| | | | | |
| Recycling and Recovery | *Increase in recycling rate (%)* | *76.0, 78.3, 80.6, 83.0, 85.5* | *Amount of waste recycled to total amount of collected waste* | *CCs and CCRC management* |
| | *Annual cost recovery rate (%)* | *35* | *Revenue generated from up-cycled or recycled products and sold packaged waste to CCRC operational cost* | *CCs and CCRC management* |
| | | | | |
| Disposal | *Disposal rate (%)* | *4.0, 3.9, 3.8, 3.7,3.6* | *Amount of waste disposed to amount of waste collected* | *CCRC management/* City/Town Council |
| | *Level of open dumping and burning (%)* | *20, 19.4, 18.8 , 18.2, 17.7* | *Amount of uncollected waste openly dumped and openly burned quantities* | City/Town Council |