

Review

Challenges and opportunities in municipal solid waste management in Mozambique: a review in the light of nexus thinking

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Abstract: As one of the least developed countries in the world, Mozambique has many challenges to overcome during its attempts to arrange the country's solid waste management system. Some of these challenges are unique to the country while many are common to other developing countries in the region as well as elsewhere. One unique challenge to overcome is the adverse impact made by the 16-year long civil war that ended in the 1990's. Financial difficulties combined with lack of proper planning/coordination has not allowed some waste-related industries to come back to full swing yet. Lack of financial, technical, and trained human resources as well as the inefficiencies in the legal and institutional arrangements are some of the issues common to many other developing countries. However, some of the challenges can be converted to opportunities relatively easily. Finding ways to capitalize on the high organic fraction of the country's municipal solid waste (MSW) is one such example. Together with a comprehensive review of the current status of MSW management, this manuscript presents a study conducted on how integrated resources management concepts may help Mozambique to make its MSW management more sustainable. Building on the existing initiatives that support recycling and other resource recovery efforts, as well as capacity and institutional development, this investigation explores how nexus thinking can help to improve the status of solid waste management. It is also interesting to note that this process will in turn help the country to achieve some of the sustainable development goals (SDGs) set by the United Nations. While proper and sustainable MSW management addresses SDG 12 in a comprehensive way, it also helps with achieving other goals such as 3, 6, and 15 to a certain extent.

Keywords: municipal solid waste (MSW); waste management; waste disposal; Mozambique; dumpsites; recycling; nexus approach; sustainable development goals (SDGs)

Abbreviations:

AGRESU: Apoio à Gestão de Resíduos Sólidos Urbanos—Assistance in Solid Waste Management in the Greater Maputo Area
 AMOR: Associação Moçambicana de Reciclagem—Mozambican Association for Recycling
 DMSC: Direcgdo Municipal de Salubridade e Cimentdirio—Directorate for Environmental Sanitation and Cemeteries
 MICOA: Ministerio para a Coordenação da Acção Ambiental—Ministry of Coordination of Environmental Affairs

MISAU: Ministerio da Saúde—Ministry of Health
 MSW: Municipal Solid Waste
 NGO: Non-governmental Organization
 PE: Polyethylene
 PET: Polyethylene terephthalate
 PP: Polypropylene
 SDGs: Sustainable Development Goals
 UN: United Nations

1. Introduction

Data on waste management in sub-Saharan Africa is scarce. This data scarcity results mainly from the lack of waste management activities in the countries. Case studies in Ghana, Zimbabwe [1] and Botswana [2] show that increasing waste volumes are usually faced with lack of financial, technical and institutional resources. Similarly, waste management is still at a low level in Mozambique. Most activities are centered on larger cities, especially around Maputo—the capital city of the country. Smaller cities and rural areas suffer from insufficiencies in all aspects of solid waste management, i.e., collection, transport, treatment, final deposit [3] as well as from lack of sanitation [4]. Illnesses such as cholera, meningitis and dysentery are often associated with the lack of proper waste disposal [5]. The health aspect and its economic dimension add to the increasing environmental problems of improper waste management such as loss and contamination of soil and water resources and loss of other resources in dumpsites, all issues being closely related [6]. The interconnection of material cycles and the need to address environmental, societal and economic aspects of sustainable development, calls for a truly integrated, or nexus approach. The nexus concept which evolved in recent years is building on and expands earlier “integrated” management strategies for single resources, such as IWRM, integrated water resources management [7]. Conceptualized as approach that integrates governance of water, energy and food across sectors and scales [8], it has more recently been argued that it is also important to consider the resources perspective of the nexus approach, which should focus on the interlinkages between water, soil and waste [9].

Mozambique is one of the least developed countries in the world. Human development index of Mozambique was ranked at the 181st place out of 188 countries in 2015 [10]. However, its gross national income per capita increased by about 24 percent between 2010 and 2015 [10]. As the

economy starts to grow, environmental problems in Mozambique have increased as well. Waste management is one such area that has grown into a larger issue that has a direct impact on the environment.

Previous research has identified the lack of knowledge and insufficient service infrastructure as the main reasons behind the inadequate waste management practices in Mozambique [3,5]. Low income, poor legal framework and institutional development as well as limited access to capital are further constraints. Industry around waste streams and recycling services have not evolved yet. Illiteracy and low education levels pose a challenge for waste management services and awareness campaigns. Initiatives taken by the international stakeholders are often ineffective due to poor coordination and thus have not fostered much sustainable changes in waste management [11].

Almost 80% of Maputo's citizens do not think that the waste collection system is sufficient yet. However, only half of the citizens are willing to pay higher fees for an improved system [5]. Waste management is not seen as an important aspect of life, it ranks after the provision with food, electricity and water [12].

Within this context, the objective of this paper is to conduct a fair assessment of the status of waste management in Mozambique and then to identify challenges and opportunities. The specific focus of the paper is on the municipal solid waste (MSW) which is still an untapped resource in many and especially developing countries. The paper looks into the possibility of utilizing this untapped resource to fill the vacuum created by lack of some other resources while preventing waste-related issues such as environmental pollution and impacts on public health. This is where the nexus approach of managing waste together with water and agriculturally used soil may assist [13]. Finally, the paper also discusses how the existing policy framework could adapt to support the nexus thinking. How managing MSW within a nexus approach may be instrumental for achieving the targets of various interrelated sustainable development goals (SDGs) which have been adopted by the UN General Assembly [14], is also briefly highlighted towards the end.

2. Generation and Composition of MSW

First reliable information on composition and characteristics of waste in Mozambique was collected and reported by the Ministry of Coordination of Environmental Affairs (Portuguese abbreviation MICOA) during the project AGRESU in 2003 and 2004 [15]. The capital city Maputo stands out as the city with the highest production of waste in Mozambique. Waste generation in the inner city sums up to 1 kg per day per person, compared to 0.56 kg per day per person in suburban areas [16]. The 1.7 million inhabitants in the city of Maputo produce a total of 676 000 kg/day of MSW and the total waste production is close to 980 000 kg/day when industrial waste is added. In rural areas, such as Niassa province solid waste generation does not exceed 50 000 kg/day. Material flow analysis for the city of Maputo revealed that waste generation increased from 397 million kilogram in 2007 to 437 million kilogram in 2014 [17].

Data on MSW collection and composition is only available for the capital. For other parts of Mozambique only estimates exist. The MSW composition depicts a clear difference between the city and the suburbs [4,5,18]. Whereas in the city center areas 68% of the MSW is made up of organics, in the suburban areas 57% of the MSW collected is fine fraction. In the limited literature available, this fine fraction is explained as sand and dust [18]. Such a high fraction of fines is not usual, but the reasons are not recorded in the literature. Detailed composition is provided in Table 1.

Table 1. Composition of municipal solid waste from Maputo (Weight %) [18]

	City	Suburbs
Organics	68	29
Paper	12	4
Plastic	10	4
Metals	4	1
Glass	2	—
Fine Fraction	—	57
Other	4	5

3. Current Status of MSW Management in Mozambique

MSW management in cities is predominantly comprised of collection and disposal at dumpsites. In the suburbs and rural areas there is no organized collection process. Instead, the predominant practice is to bury or burn [19]. Similar to many other developing countries, reuse and recycling is an integral part of everyday life in Mozambique where especially glass, cardboard and metals are being recovered [11]. In the standard waste management pyramid, recycling happens before the waste is disposed. However, when there is no established waste management practice that is backed by the laws and regulations, recycling can happen everywhere. It can happen before waste becomes waste, it can happen during transportation, and finally a major part of it does happen after it is disposed at a dumpsite, thanks to the waste pickers.

The following subsections briefly discuss the collection, disposal, and how recycling is being practiced in Mozambique.

3.1. MSW Collection

MSW collection coverage in Mozambican municipalities varies between 28% and 56% [11,20]. Collection services are highly dependent on the living standards of different neighborhood. Municipal door-to-door services are uncommon with the exception of the Somershield neighborhood in Maputo [21]. The collection services are rather divided into primary neighborhood collection, which in some districts is carried out by private initiatives, and secondary collection, which is the duty of the municipal council. The councils provide containers where citizens take their household waste (primary collection). Municipal waste collections services pick up the household waste for further processing (secondary collection). Those who produce higher volumes of MSW (over 50 liters) contract a waste management service provider for transportation of MSW to the closest dump site [18]. To increase the collection rate in neighborhoods inaccessible to waste collection vehicles, two pilot projects were carried out in the districts Urbanização and Maxaquene [15,21,22]. With the support of non-governmental organizations (NGOs), workers collect MSW in handcarts from each household and carry it to the public dumps where the secondary collection takes effect. These projects provide income to about 300 families and basic collection services for an additional 7% of the total population of Maputo. The NGOs have assisted with the recognition of the initiatives by the authorities and succeeded in including them in the MSW collection plan. Small-scale waste

collection enterprises are now being financed by the municipality [18]. As these projects improved the local waste collection profoundly, the municipal governments plan to implement the system in other suburbs as well.

Differences between waste management in rural and urban areas arise in all areas of infrastructure [3,21]. The municipal dumpsters on every block in the center of the capital city, Maputo are emptied daily. However, only few municipal dumpster can be found in the peri-urban areas, where most waste is either burned or buried. Karani and Da Costa [23] reported that in 2006 the municipal waste collection covered about 70% of the city center and 27–50% of the suburban area of Maputo. As per the latest figures [18] Maputo coverage has increased to about 82% while the national average is in the range from 40–65% [23]. The collection of waste that was disposed at the local dumpsites in the inner city of Maputo increased profoundly from 76 million kilograms in 2007 to 253 million kilograms in 2014. This increased collection reduced the uncollected waste mass from 300 million to 158 million kilograms [17]. Waste collection in the Beira municipality covers about 75% of the waste produced. Another initiative called the “municipalities development program” that was implemented in the North and centre provinces of Mozambique was also targeting to improve the MSW management services [20]. The results of this three-year program have shown that the coverage is still limited in most provinces and that infrastructure development does not automatically result in increasing collection coverage.

The lack of proper waste collection equipment and means for subsequent maintenance of them are among the major known issues hampering progress in waste collection. Vehicles used for collection include open tippers, compacting vehicles and tractors in municipal areas. Especially in the suburbs where fine fraction and rubble in MSW is high, compacting trucks with a hydraulic systems are not seen as effective [4]. Kruks-Wisner [17] critiques the inefficient development aid of some donors as the waste collection trucks given to the government cannot be maintained locally due to a lack of technical knowledge and replacement parts. In 2004, 46% of vehicles of the municipal fleet were out of order. This failure of equipment not only originates from the variety of vehicles but also from the low level of investment funds set for the maintenance of the vehicles [5]. This is not an issue only limited to Mozambique, but a common problem in Africa [24,25].

MSW transfer stations are rare in most African countries. Collection efficiency usually benefits from having transfer stations as they allow collection vehicles to travel shorter distances hence increases the time for more collections. This also allows dumpsites to be situated further outside of the city center.

3.2. Waste Disposal

MSW in Mozambique is dumped in basic open-air dumpsites in all municipalities [20]. At waste dumps, waste is generally burnt, buried and compacted. As most dumpsites are situated within the city centre, burning of waste causes air pollution and may release toxic chemicals to the environment harming the nearby residential areas.

The largest waste dump in Mozambique is Hulene site in Maputo. It is situated in a suburb of the city, about 120 000 m² large, and the only legal dumpsite in the city. About 70% of the city's MSW as well as industrial waste are dumped at Hulene [5]. At the Hulene site 12 municipal employees with little training in waste management register the entries, spread the waste and guard the site. No

daily cover is applied, thus rain can easily enter the waste mass increasing the volume of leachate. The dumpsite is not fenced and there is a residential area in less than 20 m from the site. As the literature has pointed out, the location of Hulene dump is far from the being appropriate [4,5]. There is no literature to support that a proper environmental impact assessment was conducted to justify the selection of this location. It is built upon a former wetland in close proximity to the Hulene river which serves as the source of water for the city residents. The site is also threatened by a high water table. The underlying soil is sandy and hence highly permeable. With these conditions, it is very possible that the leachate from the dumpsite can enter and pollute the nearby river and groundwater. Hulene dumpsite was reaching its maximum capacity and is scheduled to be replaced as of 2018 [26]. The new site is planned as shared landfill between Maputo and Matola and had been on the discussion tables for many years [22].

In Beira, the third largest city in Mozambique, the main waste dump is located in Munhava, Matopa and has been operational since 1972. Its location is also highly unsuitable as the area is prone to flooding and the water table is only 1.5 m deep. A new landfill site has been proposed but that proposal was also questionable due to being above ground deposition [18]. The municipalities development program aimed at converting the existing uncontrolled waste dumps into controlled waste dumps by using adapted solutions, such as deposition cells, land raise systems and mechanized trench methods [20].

Information presented above in this section only concerns the disposal of MSW that reaches the established means of collection. As per the statistic presented in the previous section the collection coverage is very low throughout the county. This questions the fate of the MSW that does not reach any of these organized processes. While some waste is buried or burnt a considerable portion is also disposed in areas not designated as dumpsites making them illegal dumps (Figure 1). This is another issue faced by many developing countries due to lack of laws or lack of enforcement of laws related to waste management.

3.3. Formal Recycling Industry

The factor limiting the waste recycling in Mozambique is the weak industrial demand for recycled materials [5,27,28]. Most recycled waste is exported from Mozambique. MICOA has initiated the national integrated urban solid waste management strategy to promote recycling as well as develop a recycling industry and corresponding markets [4].

Most industries in Mozambique were adversely impacted by the 16 years long civil war that ended in 1992. Even though the war ended 25 years ago, most industries still lay idle. The only glass recycling facility (Vidreira de Mozambique) is no exception. This facility had not been in operation since the 1990s [5] resulting in glass not being recycled in Mozambique at all. Since 2006 the recycling industry is slowly evolving but activities are mostly centered around Maputo and Beira [18]. A multinational company called RECLAM (the Reclamation Group Ltd.) is active in Mozambique and exports most recycled materials from Mozambique (PET—polyethylene terephthalate, glass, metals) [4]. Palagata, another enterprise active in the waste sector, exports paper, cans and glass bottles to international markets [28]. Only plastic (PE—polyethylene, PP—polypropylene), paper and ferrous scrap are recycled and reused within Mozambique [11,27]. The changing prices for recycled material on the international market make the local market for recyclables unpredictable and

unstable. Hence recycling becomes unprofitable for most materials in Mozambique; when the prices for paper and other materials are low, the export of these materials to South Africa stops. As scrap metals currently attain a good price, there is an active informal market leading to an export of these metals to other countries.



Figure 1. Illegal dumping of waste next to a major road and an agricultural land near Maputo (picture taken in June 2014).

There are some private initiatives and NGOs trying to increase recycling activities in Mozambique. The RECICLA cooperative processes about 15 000 kg/month of collected plastic waste to produce plastic pellets, which are sold to local factories producing household utensils [27]. The recycling of plastic waste not only serves as a good measure of waste management but also decreases the dependency on imported goods as household utilities can now be produced in Mozambique. With its success, RECICLA served as an example to other projects, e.g., environmental association SAANER in Laulane district and imparts its experience in training sessions. RECICLA also invests in the education of its employees educating them in literacy, hygiene and business [28].

The NGO AMOR is planning a paper transformation line for ecological roof shingles and a production center for handcraft and design from recyclables, thus expecting to increase the value of the recycled materials [29]. They also started lobbying for recycling at the local industries and succeeded in changing the single-use bottle system of the largest brewing company in Mozambique to a returnable glass bottle system [18]. Lobbying and advocating for recycling has been a major part of AMORs activities and they are planning to make a stable platform to connect all stakeholders of the recycling industry.

In 2015 a project between international partners, local NGOs and the Beira municipality started with the aim to implement a waste transfer and recycling center in Beira to reduce waste disposal at uncontrolled dumpsites (Nordic development Fund 2015). It was the first MSW transfer station in Mozambique and that incorporated recycling of plastics, glass and metals for export or local reuse. Organic waste is also retrieved and transformed into compost or refuse derived fuel.

3.4. Informal Recycling (Waste Picking)

Informal recycling is strongly associated with dumpsites and waste pickers. The materials that waste pickers collect from dumpsites are either used by themselves or sold to vendors who sell to the recycling industry. For instance, cardboard is collected from municipal containers and commercial institutions and sold at local markets for the strengthening of baskets or packaging for produced foods [5]. Such small private recycling initiatives are typical but the lack of industrial demand for the recycled materials keeps their value of recycled materials low. Nevertheless, by their informal waste picking scavengers make an important contribution to recycling waste and thus should be taken into consideration in MSW management strategies [11]. The informal recycling sectors need to be integrated into the MSW management plans and should be recognized as a proficient actor whose already existing networks can be the basis for an expanding recycling industry. Examples for where the formalization of such organized groups led to privatization of the recycling industry can be found in other parts of Africa [30].

To support informal collection an NGO called AMOR installed “Eco-Points” throughout Maputo to purchase recycled goods from private persons and waste pickers and resell to the recycling sector[27-29]. AMOR estimated that approximately 350 waste pickers sold about 300 000 kg of waste per month to these collection points in 2011. Goods collected at the points included paper, cardboard, plastic, glass, metal, oil and electronic waste. Involving the public into waste recycling activities encourages capacity development and environmental awareness.

Waste picking is common among all waste dumps in Africa and the Hulene site in Mozambique is no exception. On a given day there are about 100 waste pickers at the Hulene who collect food scrap, cardboard, pieces of wood, old metal and plastic bags [5,27]. Several established service providers evolved around the waste pickers to buy the materials collected from the dumps.

In Mozambique, there is no specific governmental regulation forbidding scavenging activities at the dumpsites. However, some articles of the municipal regulation are restrictive to the waste picking activities. The regulation on the components of cleansing in the Municipality of Maputo states in article 17(d) that “withdrawing, rummaging or selecting waste in the containers or other equipment (such as trucks) is punishable by a fine”. In article 26 it further remarks that “all solid waste arising from cleansing of the municipality of Maputo, whether collected by the municipal services or by duly licensed entities is the property of the Municipal Council of Maputo” [27]. Scavengers could therefore be charged with theft when they are found picking waste. In practice the municipal government does not have the will or the capacity to put this legislation into action.

The situation of the waste pickers is now improving due to the programs put together by NGOs to foster education and skills of the workers as the same NGOs also provide opportunities to improve their businesses. At the recycling centers of the RECICLA and FERTILZA projects, the workers go through compulsory literacy courses. The centers provide education on micro-business, management of personnel, plastic recycling techniques, and accountancy [31].

4. Institutional and Legislative Aspects of MSW Management

In Mozambique no single institution is responsible for the coordination of the waste management sector. The national sanitation information and communication network coordinates the governmental

bodies with its headquarters in the Ministry of Health (MISAU). On the municipal level, urban centers oversee the technical, social and economic questions. In general, the technical directions and financial support for waste management is in the hands of MICOA, sustainable development centre for urban areas and NGOs. MICOA, being one of the key players, is concerned with the adoption of strategies, norms and action programs as well as the drafting of municipal urban solid waste management plans [4]. In Maputo, the municipal councilor for public and environmental health overlooks solid waste management. The municipal councilor appoints the municipal directorate for environmental sanitation and cemeteries (DMSC). The DMSC employs about 600 workers including truck drivers, garbage collectors, street cleaners, dumpsite managers and administrative staffs [21]. An exception from the given scheme is the management of hazardous waste which is managed by MICOA and the Environmental Ministry and biomedical waste which is handled by the Ministry of Health [16].

With this institutional setting the roles and responsibilities are partly ill-defined resulting in institutions doing the same tasks without knowing of each other. This leads to unnecessary duplication of efforts, wasting the scarce resources available and reducing the effectiveness of the solid waste management programs. There is a lack of implementation of waste management regulations and laws resulting from insufficient waste education [5]. Another reason behind this is the lacking cooperation between waste controllers, municipal police, national police and the central government. Studies show, that municipal institutions are suffering from unqualified and unmotivated employees as well as disagreements between the authorities and the private sector [32].

The already existing legislation and policy framework for solid waste management in Mozambique is mainly concerned with the requirements for licensing and auditing of public and private institutions involved in solid waste management. It remains very general and weak in the provision of policy for the reuse and recycling of waste. Obligations mentioned in the framework such as waste reduction, waste separation at the source and treatment before deposition are rarely enforced. Often responsibilities are appointed to “all waste-generating or waste-handling entities” leaving a lot of room for interpretation. According to Cambule and Pereira [33] new regulations on MSW management have been introduced. It remains to be seen if and how they are implemented and enforced.

Maputo and Beira have annual solid waste management plans and programs [18]. Further municipalities are currently producing such master plans. The government of Mozambique is in the process of introducing a strategy for integrated MSW management to foster the technical development of MSW management and to create a sustainable institutional and management framework by 2025 [18]. This strategy aspires to involve different stakeholders in MSW management and incorporates design, implementation and maintenance of the MSW management systems. Focus of the strategy is the construction of proper landfills in the future with methane flaring, the construction of waste transfer and recycling centers and the use of waste to produce energy.

5. Understanding the Recovery Potential with a Nexus Mindset

Formal means of material recovery from MSW is evolving in Mozambique, but at a very slow pace. Compared to the sharp increase noticed in MSW generation in Maputo and elsewhere in Mozambique, the efforts in material recovery, including recycling, has not shown any significant growth [17]. Only three municipalities of Mozambique have implemented formal recycling

activities [11]. The few positive initiatives taken to increase the volume of formal recycling have not been able to recycle more than 1% of the total MSW volume.

Most developed countries use different combinations of recovery, landfilling and incineration in their MSW management models. Technically there is no harm in developing countries to learn from the developed countries. However, the real issues arise during the adaptation of the technologies to the local context and finding funds to implement new solutions. This is perhaps where we should start thinking outside the box and try to find solutions that may fit better to the local context. This is where the nexus thinking can facilitate initiatives towards increasing the resource usage efficiency.

One noticeable difference in MSW composition between a developed and a developing country is the amount of organics which is usually higher in the developing countries. For example, for Maputo it is as high as 67%. This means that most of the material collected is degradable and can be put back to good use, which holds for other African countries as well, e.g., Ghana [34]. Example products are compost, biogas, biochar, and if nothing else works, energy production through incineration. The core idea of nexus thinking is the integrated management of more than one resource in one management model to capitalize on the synergies. While the organic fraction of waste belongs to MSW management, properly designed integrated management model of MSW can also bring benefits to the soil and land management through compost and biochar or the energy sector through biogas and incineration. In addition, increased recovery and recycling of organic as well as traditional recoverable materials such as paper, plastic, and metal (will also make a considerable reduction in the volume of MSW that needs a place for final disposal.

In general, adopting and implementing policies for managing MSW would be instrumental for achieving respective targets of the SDGs briefly mentioned in the Section 1—Introduction. Particularly several targets of SDG 12, which is about ensuring sustainable consumption and production patterns are relevant in this regard: 12.5 targeting reduced waste generation through prevention, reduction, recycling and reuse; SDG 12.2 targeting management and efficient use of natural resources; SDG 12.3 aiming to reduce food waste and SDG 12.4 focusing on the sound management of chemicals and all wastes and the reduction of their release to air, water and soil. Reducing the amount of waste released into the environment would add to achieving SDG 6.3 targeting the improvement of water quality by reducing pollution) and SDG 15.1 focusing on the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems. Impacts on health are captured in SDG 3.9 aiming to reduce the number of illnesses and deaths from hazardous chemicals and air, water and soil pollution and contamination. Further co-benefits for other SDGs could be achieved by integrating MSW management into a nexus approach as outlined in the following subsections providing some examples of how Mozambique may be capitalizing on the increase in the MSW flow from a nexus perspective.

5.1. MSW Composting

Given that biomass makes up a largest portion of MSW produced in Mozambique, focusing on recovery of organic materials is a necessity for good practice waste management. It not only reduces the volume of MSW that needs to be disposed, but also makes the nutrients available again and creates new jobs. Processing biological waste is a basic process that does not require a lot of technology or investment. With proper input waste streams and handling of the composting process,

it is likely to succeed on the small and medium scale [25]. Using this compost on urban and peri-urban areas for improving soil quality and enhancing food production would contribute to achieving SDG target 2.4 which takes aim at sustainable food production and improved land and soil quality.

In 2006 there was only one small composting plant in Maputo city within the Tunduru garden of the central business district [5]. The directorate of parks and gardens managed it to compost garden waste and tree leaves. In 2008 the NGO Caritas together with the municipal directorate for markets and fairs started a project called FERTILIZA for recycling of organic market waste [27]. The initiative now produces around 700 kg of fertilizer each day [28]. Due to the low demand for compost the project set up a plant nursery to showcase the use of compost. The initiative has been kept purposely small-scale (same as RECICLA) to keep a low economic risk and to maintain sustainability [28]. In Beira the Terra Nova initiative has established a collaboration with the municipal authorities where they receive the collected waste from the municipality and separate the organic fraction [18]. The company produces about 600 000 kg of organic compost yearly. Such initiatives, if economically successful and managed properly in terms of working conditions, help achieving SDG 1 (end poverty) and SDG 8, which is about sustainable economic growth and decent work for all.

Backyard composting is not applicable in most parts of Maputo as there are no or too small backyards. Composting is not culturally popular among Mozambican citizens hence the quality the compost produced in the backyards would be low, even if attempted. Small-scale composting has become successful in South Africa and Congo in areas with large gardens and with residents holding cars that are able to bring the organic waste to centralized depots [5]. This type of decentralized neighborhood composting would require dedicated staff, such as trained compost supervisors, making it more costly, but would ensure sufficient quality. Thus the most applicable solution for composting in Maputo and other cities in Mozambique could be centralized sites which are ideally located close to dumpsites [5,35]. Community level composting requires awareness raising among its citizens as the attitude of citizens towards such facilities was found to be mostly negative, caused by the closeness of the composting units to the residential area and the lack of composting culture [35].

Similar to the other recycled materials, there is a lack of demand for MSW-derived compost in Mozambique and other African countries. Without subsidies farmers aren't willing to pay the complete production price for compost [36]. This MSW-derived compost could be also used as daily cover material at disposal sites such as Hulene dump to control odor, vectors, wind issues (uncovered waste blown by wind) and some infiltration [5], thus addressing SDG 11.6 targeting air quality and waste management in cities.

5.2. Biomass for Energy Production

Apart from composting, organic waste can also be used for bioenergy production. Used cooling oil collected in the "Eco-Points" is already used as biodiesel. The project is being implemented in Mozambique since 2013 but it has already been successfully tested in South Africa [29]. An investigation on the reuse of waste frying oil in the Kampfumo district of Maputo revealed that a large number of return points need to be opened in order for it to be profitable [37]. Residues from timber-processing are a promising source for bioenergy production [38]. However, agricultural residues have less potential for success as a business model as agriculture in Mozambique is

dispersed and subsistence-oriented. The feasibility of reusing cashew nut shell for energy production has been tested in a small-scale pilot test site in Nampula and showed that reusing high-energy content agricultural waste can be a competitive alternative to standard diesel powered systems used in many remote areas [39]. Another study on using refuse derived fuel to supply a cement factory in Mozambique underlined its potential to reduce carbon emissions but also calls for enhanced waste management to put the findings into practice [40]. A feasibility study assessing the location of a possible biomass power plant found that a proposed power plant close to Maputo could provide for up to 32% of the energy consumed in the city [41]. This would contribute substantially to achieving SDG target 7.1 (access to affordable, reliable and modern energy services) and 7.2 (increase substantially the share of renewable energy).

6. Facilitating the Capacity Needs with Nexus Thinking

There are three main components influencing the development of sustainable waste management system: technology, money, and organization. The technology should be about suitable and adaptable technical solutions, and then there is a need for adequate economic instruments to sustain the services. Finally and most importantly there should be an organization that has the capacity to implement and sustain both the technical and economic measures. The issues related to the technological aspects were briefly addressed in some of the previous sections. This section focuses more on the interaction between the financial and organizational aspects. The following subsections specifically pays attention to the waste taxation in Mozambique and how the institutional arrangement can be improved with some external adjustments such as education and formal integration of waste pickers into the system.

6.1. *The Success Story of Waste Taxation as a Measure of Cost Recovery*

Building up a sustainable waste management system is highly dependent on appropriate funding of the services. Lack of funding may lead to problems such as availability and maintenance of equipment as well as organizational capacity issues such as insufficient and under qualified staff. This is specifically hard when Mozambique has a high dependency on international funding. Over 50% of the public spending in Mozambique is financed through foreign aid making it one of the world's most donor-dependent countries. Mozambique received US \$58 per inhabitant in 2005 compared to an average of US \$26 for other sub-Saharan countries [21]. The international aid may assist in building waste management infrastructure. However, lasting sustainability can only be achieved by a government making rational and independent judgments about public expenditures and their distribution across different sectors.

In 2004 the municipality in Maputo spent US \$130 000–170 000 per month on its waste management system with the highest spending for fuel (Figure 2). The actual costs of the system were about double of the collected waste taxes [5].

In order to introduce economic instruments into legislation the Gesellschaft für Technische Zusammenarbeit conducted the technical assistance project AGRESU (Apoio à Gestão de Resíduos Sólidos Urbanos) in Mozambique from 2002 until 2010 [15,16,21]. One of the first steps of the project was a waste tax introduction in 2002, which was cancelled only a few months after its

implementation. Due to poor services and insufficient public information about the waste fee the public's opinion on the tax was overwhelmingly negative. One of the measures taken after these protests was the contracting of the private collectors by the municipalities to improve the municipal garbage collection performance. Mozambique at that time was one of the few countries that formally contracted small-scale waste collectors [21]. This proved to be a positive effect for the municipal government as generally privately operated services are less expensive than public sector services which experiences from other developing countries have shown [5].

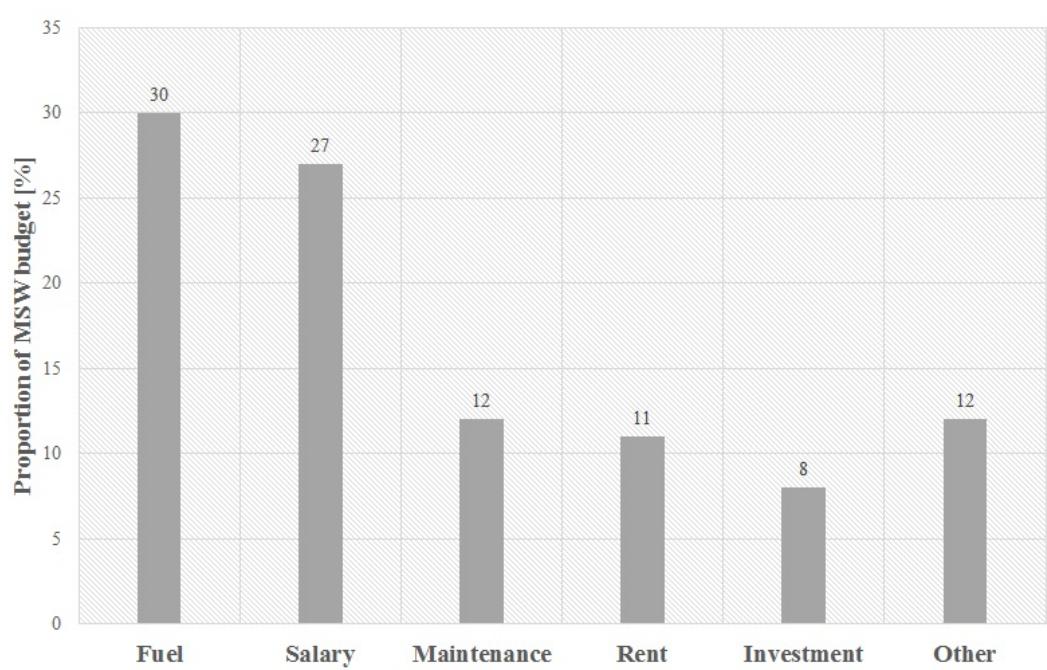


Figure 2. Maputo solid waste management budget 2004 (adapted from [5])

Before the reintroduction of the tax in 2003 extended public campaigns explaining the need and the use of the tax were run. Furthermore, the payment of the tax was introduced being attached to the electricity bill—an already established collection system covering 90% of the households in Maputo. This combination with a basic facility increased the residents' motivation to pay the tax. The strategy of coupling the waste fee to an already existing public facility proved to be very effective and shows that the way of collecting taxes is an important means in the development of a waste fee system. It was calculated that about US \$2 per month and household are needed to make the waste management system economically sustainable, which is less than 0.6% of the average available income. However, with the introduction of the fee, the price per month and household was set to \$0.8 with the vision of increasing the price steadily to US \$2 [16]. Hence in 2007 the first raise of the tax was introduced making higher income households pay up to two times the price of average income households. The fee was also linked to the energy consumption of the user. Now high income households pay higher waste fees than regular energy users. The linking to the energy consumption encountered significant opposition by the civil society but was eventually defended by the municipality [18].

Non-household waste producers were included in the tax system as well. In 2006 a licensing and registration system (proof of service) was introduced. Producers that generate high quantities of

waste are on their own responsibility for the collection and disposal of their waste. A monthly disposal fee for these producers was included based on their quantified average waste production.

The revenues from both household and non-household taxes increased from \$50 000 (2004) to \$310 000 (2012) per month which covers about 69% of the total costs of waste management [16]. The necessary and planned development of the tax within the next years to achieve a self-financed system shows that self-sufficiency can almost be reached in few years (Figure 3).

Domestic waste fees are now collected by all municipalities, mostly through the electricity bill. Further, a gate fee was introduced at the dumpsites. However, until now only three municipalities have implemented a waste fee system for commercial waste producers. But in general it lacks means to enforce it and currently there is no solution for those who are unwilling to pay [11].

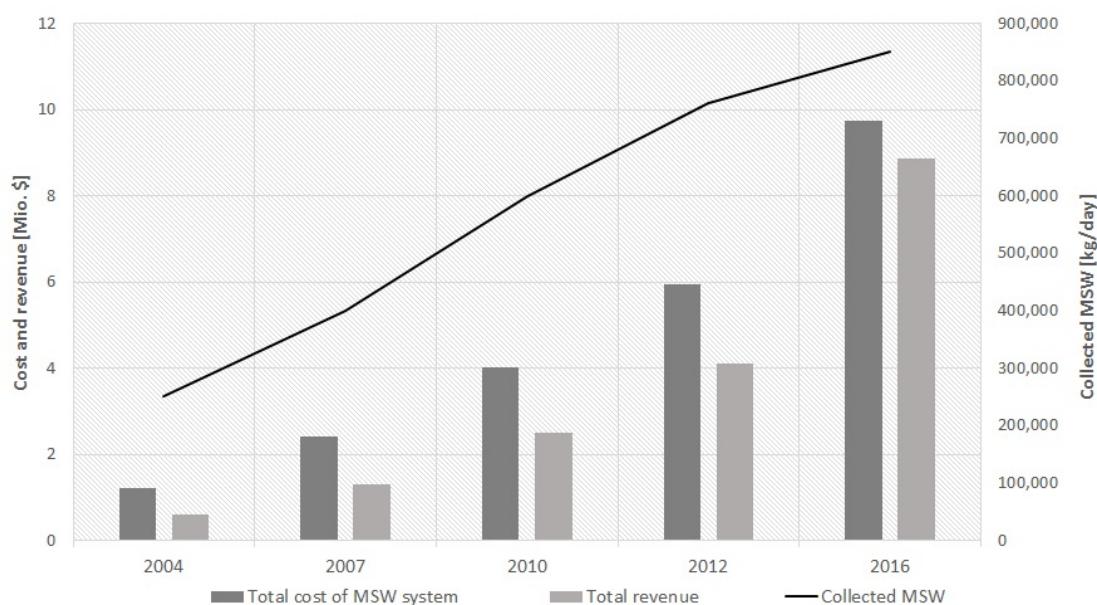


Figure 3. Actual and planned cost revenue for waste management in Mozambique (adapted from [16]). Data from 2004 to 2010 are actual data. Data for 2012 and 2016 are estimated based on planned tax increases and investments into waste infrastructure.

6.2. Waste Education

Waste education needs to be an important element within the institutional development, in particular when aiming at a nexus-oriented management. All stakeholders concerned with waste management need to be educated on the environmental and health issues and risks associated with mismanagement of MSW. It should also cover appropriate ways of handling different types of waste. To date, awareness raising and public participation are on a low level and littering as well as waste mismanagement are common phenomena [32]. Awareness raising and educational programs about sanitation and waste handling have been conducted in a few municipalities (Manhiça, Dondo and Ilha) with the help of international partners. The sustainability of the actions after the withdrawal of the international partners has been insufficient [19].

Waste education should not end with the education of all staff involved but rather encourage them to widen it to local and religious communities, vendors in open markets, private and government control bodies, schools, the commercial sector, private security services, local authorities, non-governmental organizations and individual citizens [5]. Educating the Mozambican citizens on appropriate waste management requires a strenuous effort that can only be met by integrating as many institutions as possible into the process.

To increase the human capacities for waste management, educational programs in the national universities should be improved. As better expertise and young professionals will increase Mozambique's potential to handle waste in a sustainable fashion, professional waste education needs to be put into focus [42]. Currently the focus for environmental study programs such as environmental engineering lies predominantly on water and soil related issues. This can be an attractive opportunity for the academia to introduce waste management into the formal education system, and it is even better if the existing water and soil-oriented structure can be updated to include the nexus approach of integrating waste management together with water and soil.

6.3. *Integration of Waste Pickers*

The formation of an organization for the waste pickers of Maputo is seen as an effective way to quickly improve Maputo's waste management system [5]. An organization could integrate the waste pickers recycling into the official waste management system, thus making it more effective. Waste pickers would be officially employed and their recycling activities could be improved by shared knowledge and better technology. This could follow the example of waste pickers in Brazil which obtained legal recognition and rights by building up their own organization and even a global networking group among waste pickers [27]. It is a win-win situation to integrate informal waste recycling activities into the official waste management system and recognize the economic, social and environmental benefits that result from informal recycling as the establishment of a new formal waste recovery system is very costly and takes up time [43]. The already existing and well-established informal waste recovery systems in Mozambique hold an enormous potential by further developing and integrating these systems in the official management strategies of the municipality.

7. Concluding Remarks

MSW management sector in Mozambique has not evolved yet to cater to the entire population. Being one of the least developed countries, Mozambique has more challenges to overcome during the process of organizing its MSW management system. Technical expertise, access to capital, and institutional arrangements are the main three aspects that need attention.

Even though about 85% of the MSW generated could be recycled or composted, only less than 1% of it is currently recycled or recovered. Establishment of waste transfer centers can help increase not only the MSW collection rates, but also recycling efforts. Integration of waste pickers recycling activities into the official waste management system would make their work more effective as their recycling activities could be improved by shared knowledge and better technology. The provisions of policy for the reuse and recycling of waste should be given due consideration emphasized in the existing legislation and policy framework for solid waste. Obligations mentioned in the framework

such as waste reduction, waste separation at the source and treatment before disposal should also need to be enforced.

Biomass makes up the biggest percentage of waste produced in Mozambique. Composting of organic waste is a sustainable waste management option which does not require a lot of money or expensive technology. However, finding appropriate and stable markets for these “waste products” is also important. The few small-scale composting plants that are currently in operation produce little revenue due to the lack of a proper business model. Bioenergy is promising option for the reuse of organic waste in MSW. For this more comprehensive technical investment is necessary, but studies have shown that it has the potential to supply one third of Maputo’s energy demand in a sustainable way.

Recent steps taken by the government authorities and the activities initiated by NGOs have raised awareness and also improved MSW collection rates. The more recent establishment of efficient governmental management structures and the introduction of the waste taxes in some municipalities have proven to be an effective instrument to increase the financial resources needed for waste management. It is apparent that more aggressive steps should be taken to capitalize on the benefits available through material resources recovery. Based on the high percentage of organics in the Mozambican MSW, waste composting and harnessing energy would be the most logical steps. Further improvements in this direction would benefit from taking a nexus perspective, with co-benefits for various sectors such as agriculture, energy and health. Managing MSW in a nexus-manner would also be instrumental for achieving various interconnected sustainable development goals, particularly SDG 12, to ensure sustainable consumption and production patterns, with targets 12.2–12.5, addressing aspects of waste management. Further positive effects will be achieved for SDG 2.4 which targets sustainable food production and improving soil quality. Additional benefits will be achieved for SDG 3.9, aimed at reducing deaths and illnesses from pollution, SDG 6.3, targeting water pollution, SDG 7.2 on renewable energy, SDG 11.6 on reducing environmental impacts of municipal waste and finally SDG 15.1, which targets the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems.

Conflict of interest

The authors declare no conflict of interest.

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