Initial Environmental Examination

April 2017

Myanmar: Third GMS Corridor Town Development Project
"Mon State" (Part 2A of 4)

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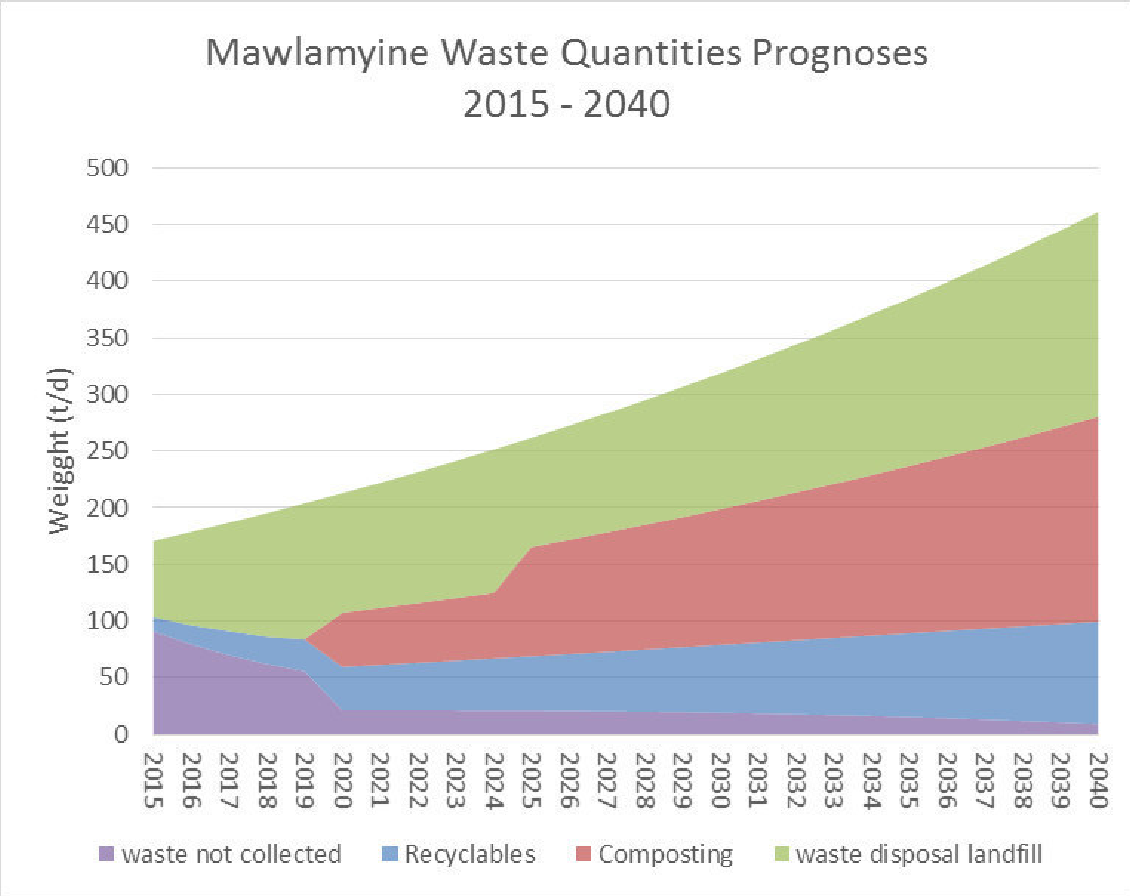
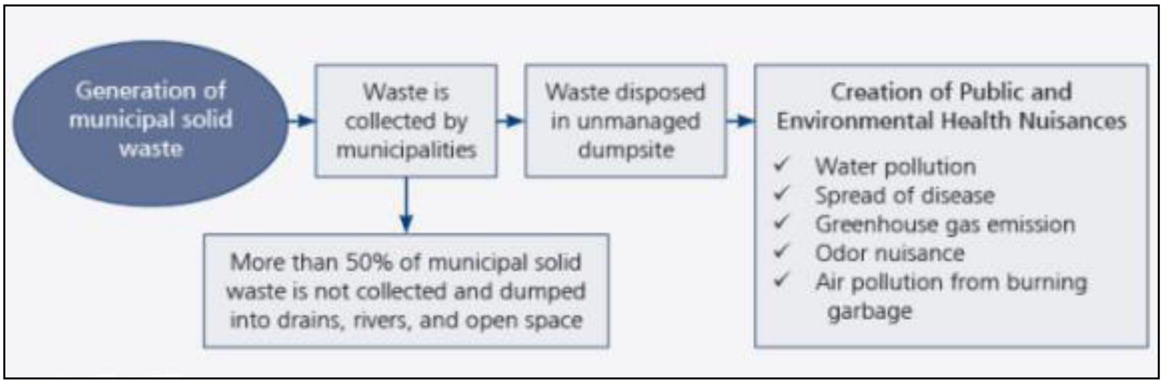
Figure 3-23: Current and Prognosis Waste Generation and Treatment



3.3.3 SCENARIOS

The previous paragraphs showed the existing solid waste situation and the future challenges as shown in **Figure 3-24**.

Figure 3-24: Typical Scenario of Solid Waste Management



At the moment, waste collection is not done appropriately, transport and disposal is at a low level and disposal of waste is not acceptable at uncontrolled dumpsites with open fires and no treatment or prevention of leachate, with potential pollution of the groundwater and water supply sources.

Also the financial struggle for the municipalities related to the waste management is also a constraint for further development in this sector. The waste collection fees are paid directly by each household and usually apply to collection only. The fees are generally not enough to cover the solid waste system's upstream costs.

To change the existing scenario with about 50% of uncollected waste and disposal of the waste in unmanaged dumpsites the following scenario as shown in **Figure 3-25** is proposed.

Figure 3-25: Proposed Scenario of Solid Waste Management

The above scenario can be implemented through the following:

- Launching a long Term **Strategy**
- Launching a **Vision**
- Establishing **Targets**
- Introduction of an **Integrated Sustainable Waste Management** Plan.

3.3.4 STRATEGY

STRATEGY

A Strategy is about the future, about thinking about the place of waste management and urban environmental health over the longer term. This project has a planning period of 25 years, from 2015 till the year 2040.

Part of a strategy is an Action Plan which covers actions to be implemented the first five years.

Many countries have, or are in the process of developing, national policies and sector strategies on waste management. These policies typically set out needs and priorities, key areas of focus and sectoral targets for the nation as a whole, and provide a national framework for regional/local Strategic Solid Waste Management (SWM) Plans.

One of the Strategy's Aspects: the "Waste Management Hierarchy", a top-down level of how to manage municipal solid waste is shown in Figure 3-26. As shown in the figure, the 3Rs of "Reduce, Reuse and Recycling" formulate the most preferred options and the most part of the hierarchy, because the main goal of solid waste management is reducing and eliminating adverse impacts of waste materials on human health and environment to support economic development and better quality of life.

Figure 3-26: Waste Management Hierarchy

TARGETS

The Main Target for SWM is:

"to keep the city clean and sanitary by removing waste from the living areas and disposing of it in an environmentally acceptable manner"

This main target is more specific subdivided into short - & medium term targets and long term targets which are presented in **Table 3-12**.

Table 3-12: Targets for the Short, Medium and Long Term

Short & Medium Targets
• expand collection service to 95% by 2020 by using an efficient collection system
• Implement a controlled landfill site for disposal

• Promotion of waste volume reduction (3Rs) • Provide a Solid Waste Management financial base based on new fee collection system • Strengthening of Institutional set-up • Strengthen public sanitary education, public awareness and community participation • Introduction of private-sector participation
Long-Term Targets
• Expand collection service to 98% by 2025 by using an efficient collection system • Implement a **sanitary** landfill disposal • Continuous Promotion of waste volume reduction to nearly zero waste • Provide a sustainable SWM financial base • Continuous Strengthen public sanitary education, awareness and community participation • Expansion of private-sector participation (PPP)

The target levels for environmental improvement for solid waste management are shown in Table 3-13, with a minimum level, comfortable level and an all amenities level, which means that all facilities are in place and functioning plus good governed solid waste management.

Table 3-13: Target Levels of Environmental Improvement SWM

1	Minimum Level	To collect all generated solid waste within a service area on a regular basis (at least once a week) and disposal at controlled landfill site.
2	Comfortable Level	To collect all generated solid waste within a service area on a regular basis (minimal twice a week) and disposal at sanitary landfill site.
3	All Amenities Level	To have all facilities in place to collect all generated solid waste within the township on a regular basis and to treat the collected waste adequately then dispose of the remnants.

At the moment, the minimum Level requirements are not met, because only about 50% of the generated waste is collected (although on a regular base twice/week) and the minimum level for disposal at controlled landfill sites is far behind, even not existing, at the moment. All waste is dumped in open dumpsite without any protection.

Therefore the project has to start to achieve Level 1: Minimum Level initially, and the subsequent levels 2 and 3 for the Medium - and Long-Term.

3.3.5 INTEGRATED SOLID WASTE MANAGEMENT (ISWM)

COLLECTION

The collection system is at the moment inadequate, only about 50 -55% is collected. To reach the Minimum Target Levels of Environmental Improvement Solid Waste Management for collection, additional collecting measures have to be implemented.

To maximize the Waste Collection, the following measures are proposed:

- Modernize waste collection means (primary collection)
- Establish a high rate of sorting, separation
- Improve waste transportation to disposal site (secondary collection)

The actions undertaken are presented in the table below.

Table 3-14: Proposed Collection Improvement actions

Collection	Weaknesses	Action required
Primary collection in the Wards	works more or less properly when tariff / fee structure has been implemented	no action short term (except collection fees to be established)
Source Separation at Primary collection level	Not present at the moment, highly recommended to implement separation at source to collect less mixed waste biodegradables	Supply of different (colour) containers for different sorting, e.g. one container for dry recyclables, one container for wet recyclables (compost) and one container for the remaining fractions
Secondary collection	Township level and transport to disposal site: no sufficient vehicles and collection points	investment in additional collection vehicles and collection containers, implementation of collection points at several areas in the Towns

PRIMARY COLLECTION

Source Separating Collection Containers

Many public works departments assume that, in tropical countries, it is necessary to collect waste every day. Even in hot climates, where containers are appropriate for the volume and type of waste, this can often be reduced to two or three times per week, and sometimes, in combination with separation of organic waste, to once per week. This makes collection more affordable, while maintaining an acceptable hygiene standard.

Several containers will be used, examples shown in **Figure 3-27**, each with a different purpose, such as dry recyclables, organic waste and residual waste. Designing and modernizing a collection system also involves optimizing routing, and will probably involve reducing the frequency of collecting each type of waste. The goal is to increase efficiency.

Collection Vehicles

Collection can be done in several ways, using small carts manual, small tractor or small truck or more sophisticated means as full automatic hydraulic compressor trucks.

The main practical advantage of compactor collection trucks is that they can compress waste to smaller volumes (if compressible). In most countries in South-East Asia, more than half of the waste is organic and dense, inert materials, or bulky wastes, which are not compressible.

Normally compacting trucks are large trucks and they might be too wide for the streets in the towns. Compactor trucks use more fuel than standard trucks.

Figure 3-27: Examples of waste collection bins 240 and 1100 litres

SECONDARY COLLECTION

Secondary collection is the collection from collection points to the Landfill site location. This is normally executed with larger waste containers (>3m3) and larger transfer trucks with large containers (12m3 or more), as shown in Figure 3-28, which can be placed at several collection points (CP) in the town.

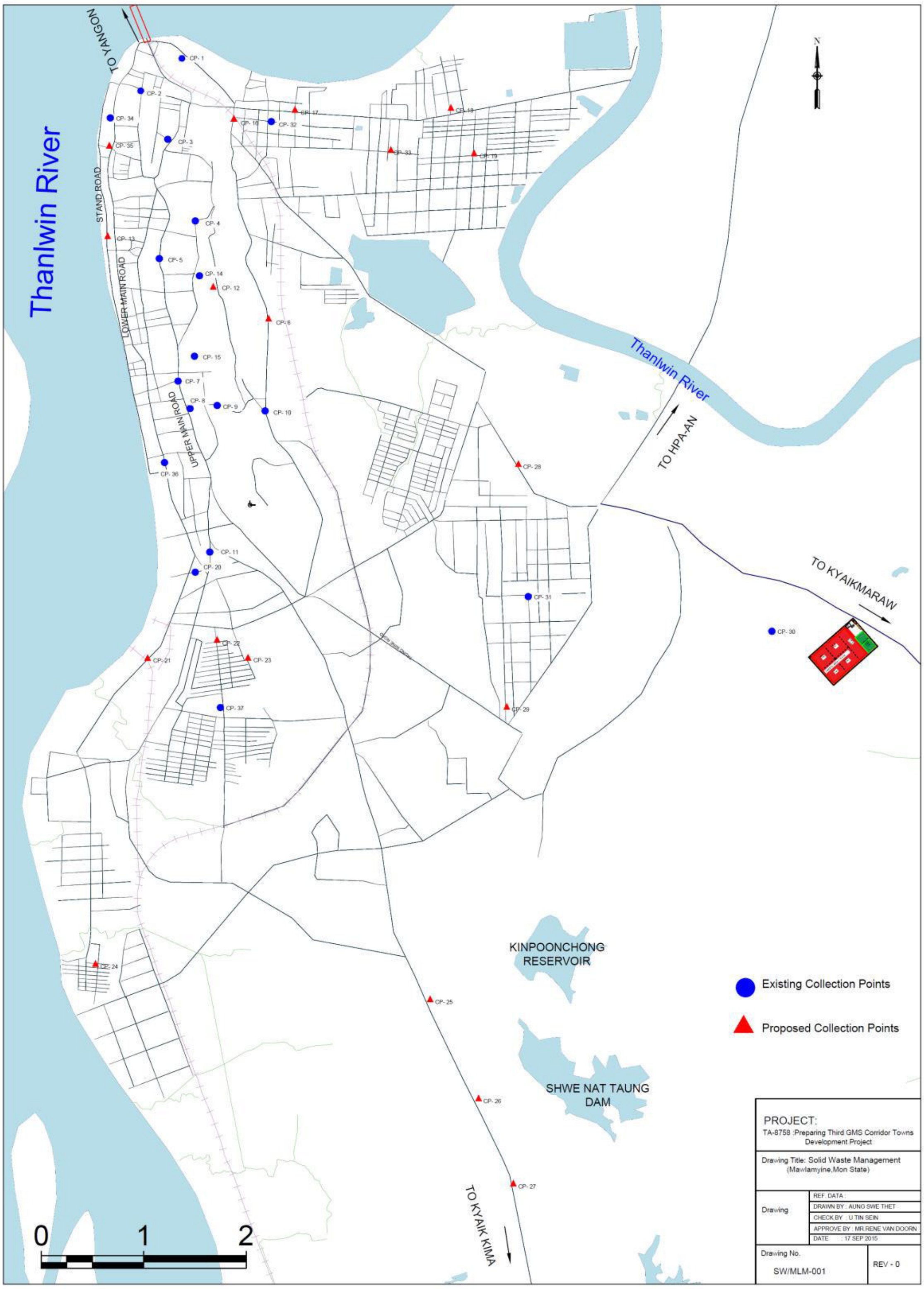
Figure 3-28: Examples collection containers 3 & 6 m^3 hook-lift system

To transfer these containers a hook-lift system is a very efficient way to lift and transport these containers with examples of hook-lift trucks shown in Figure 3-29.

Figure 3-29: Example of Hook Lift trucks

The location of the existing collection points and proposed ones is indicated on **Figure 3-30** (details in Appendices).

Figure 3-30: Map with Collection Point location



TRANSFER STATION

Transfer stations are used for further transport of the primary collected waste to the Landfill, the Compost Plant or Recycling Company. The primary collected waste, compost and recyclables are tipped in much larger containers, 12m^3 or 15m^3, and transported with a larger Hook-lift Truck (sometimes with a trailer for very large distances, e.g. >25km) to the dedicated final sites.

The economic viability of a transfer station depends on the critical distance of the solid waste system:

- The net distance from each ward centroid to the dump site in Kyaikmayaw is estimated based on the main road network as described in Figure 3-31 below. The wards are located between 1.5 and 12 km far from the dump site. The further wards are located near Mawlamyine Bridge or on the way to Mudon.
- Then the critical distance is calculated based on the formula:

$$Critical\ distance\ (km) = \frac{\sum distance * Waste\ collection\ (tons\ per\ day)}{\sum Waste\ collection\ (tons\ per\ day)}$$

The waste collection is estimated 47% of total waste generation in 2014 and 98% in 2040.

The waste quantity per ward is adjusted by adding the waste generated by markets in downtown area (as detailed in Table 3-10, there are 10 markets in downtown area and one market in PharAuk village), estimated to 28 t/d in 2015 and 77 t/d in 2040.

Based on the result detailed on Table 3-15, the critical distance is **Cd = 671/78 = 8.6 km.** The Critical distance is similar in 2014 and 2040 because growth rate is assumed as constant through the years. Even by assuming a higher growth rate in the South near Mudon, the critical distanced remains under 10 km. Some studies include traffic factor to the critical distance. In Mawlamyine the traffic is relatively fluid and would not affect SW trucks pattern.

Classic dumpers of 7 to 10 m3 capacity are usually economically interesting when critical distance is below 15 km. In Mawlamyine the critical distance is below 10 km. The wards are located less than 12 km far from the future landfill.

Then there is no specific need for a transfer station creation in downtown area.

Note: In addition to the cost consideration, several factors are disadvantaging the transfer station option:

- A lack of available public space, especially in the centroid of Mawlamyine wards which is located in downtown area;
- A reluctance from neighbourhood regarding a potentially noisy and smelly facility;
- Difficulties for driving a long-haul truck in downtown area.

Figure 3-31: Main SW collection routes in Mawlamyine

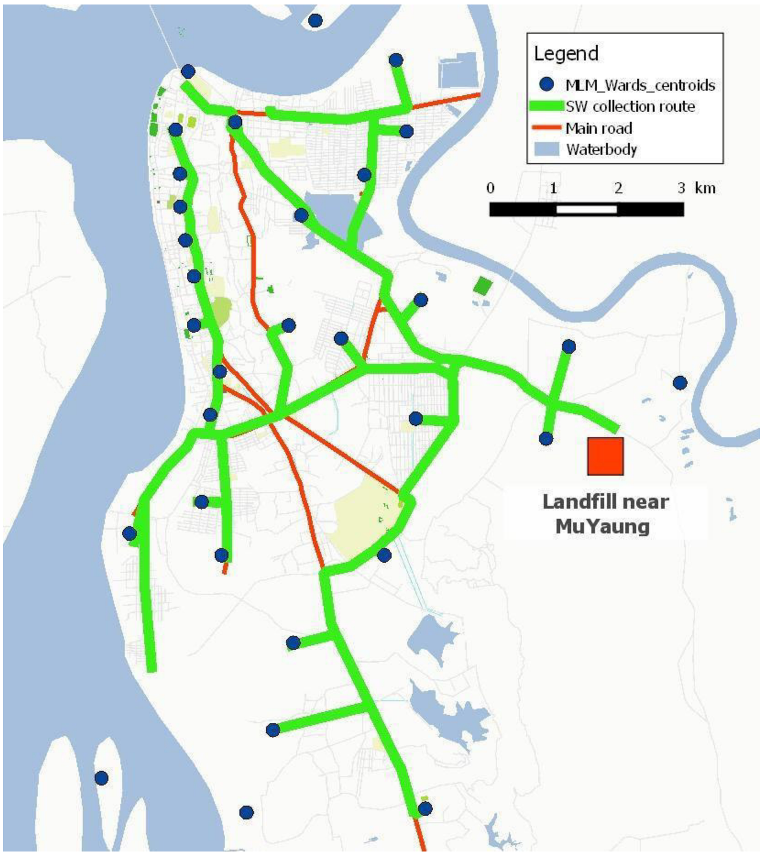


Table 3-15: Critical distance calculation for Mawlamyine Wards

Ward	Name	Distance to landfill (km)	Pop 2015 ratio Census	Waste collected 2015 (t/d)	Distance x Waste collection
1	Zayar Thiri	7.9	10912	2.75	22
2	Thar Yar Aye	6.7	5919	1.49	10
3	Shwe Myaine Thiri	8.9	23862	7.33	65
4	Hlaing	6.4	24429	6.16	39
5	Kyaik Pa Nae	9.3	7792	3.28	30
6	Auk Kyin	8.2	10350	2.61	21
7	Mandalay	9.3	5346	1.35	13
8	Hpet Tan	12	13965	7.45	89
9	Shwe Taung	11.4	10320	2.60	30

Ward	Name	Distance to landfill (km)	Pop 2015 ratio Census	Waste collected 2015 (t/d)	Distance x Waste collection
10	Sitke Gone	10.8	8088	3.35	36
11	Mayan Gone	10.3	4999	1.26	13
12	Papae Tan	9.7	5543	1.40	14
13	Bo Gone	9.1	7782	3.27	30
14	Maung Ngain	8.1	8876	3.55	29
15	Kwin Yet	7.4	12229	3.09	23
16	Mupon	9.3	10735	2.71	25
17	Thiri Myaine	8.8	13472	4.71	41
18	Thiri Mangalar	8.4	6322	1.60	13
19	Myae Ni Gone	7.6	7360	1.86	14
20	Zay Kyo	6.4	15530	3.92	25
21	Zay Yar Myaine	5	3265	0.82	4
22	Myaine Thayar	4.2	10758	4.02	17
23	Kyauk Tan	11.2	8029	2.03	23
24	Naung Kha Yi	11.4	6233	1.57	18
25	Ngan Tae	4.4	5340	1.35	6
26	Chauk Mile	1.6	4489	1.13	2
27	San Gyi	8.8	1399	0.35	3
28	Gwe Gone	10.9	5516	1.39	15
	Total	**233.5**	**258 860**	**78 t/d**	**671**

3.3.6 RECYCLING

INFORMAL SECTOR

Waste management systems in the cities of many developing countries could not be managed without the informal sector: waste pickers, scrap collectors, traders and recyclers.

This sector is often not officially recognised and acknowledged, yet its members contribute significantly to the waste management of cities, by collecting, sorting, processing, storing and trading waste materials in the recycling value chain.

The informal recovery of recyclables from the solid waste system reduces overall solid waste management costs for municipalities. If material is recovered through door-to-door collection by the informal sector, this material no longer needs to be collected, so all expenses – collection, transport and disposal – are reduced according to the amount that is recovered.

At the moment the Informal collection of recyclables in the town works good and at no costs for the municipality, therefore no further action required in this sector.

FORMAL SECTOR

There is no Formal collection of recyclables by the municipality. As mentioned before the informal sector works well and there seems no need to further collect recyclables. However, the today's informal collection rate of about 17% can be improved to 20% through the Formal Sector.

A higher separation can be implemented by introducing at schools, township offices and other official buildings the separation and recovery of recyclables using 3 different colour containers for:

- recyclables ("dry waste")
- compost ("wet waste")
- remaining fractions

At the same time when this recyclables recovery system is introduced the compost fraction will also be separated which will benefitting the municipality cleansing department at the same time. The Recycling Chain as practised in many countries all over the world is shown in Figure 3-32.

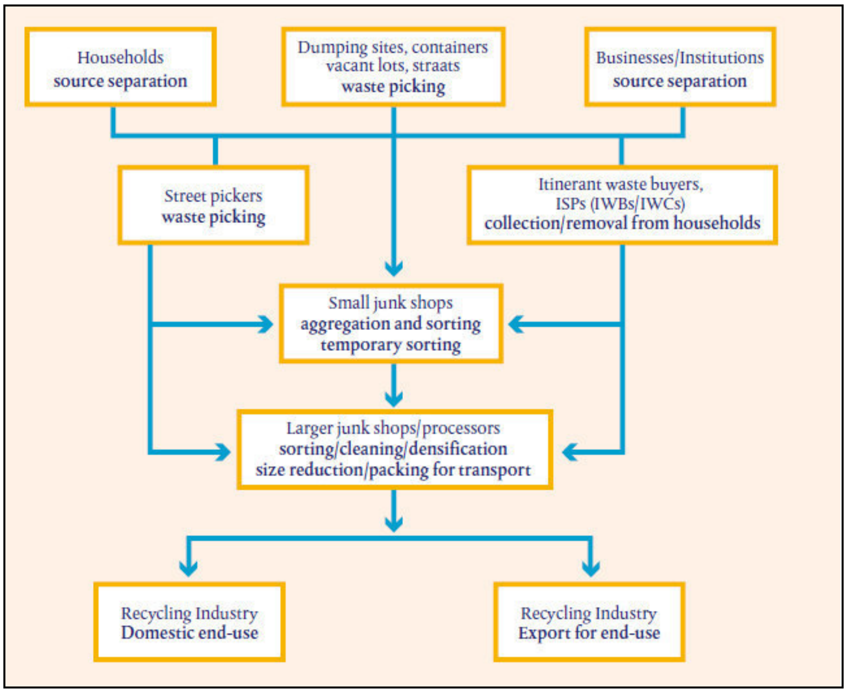
In this project it is envisaged to purchase 240 l and 1,100 l containers dedicated for separation of the recyclables.

There is a common misconception that recycling can finance, or provide income to support, new solid waste activities. Unfortunately, this is generally not the case, for several reasons. First, those materials that are profitable are probably already being recycled by the private informal sector. Examples of this kind of recycling include collecting cardboard from shops, collecting and selling ferrous and non-ferrous metals, and buying bottles and cans from households. The existence of informal recycling initiatives is at this moment well organised in town.

In most developing countries, 15-20% of the waste generated is managed by the informal sector, providing financial and environmental benefits to municipalities.

This schedule can easily be implemented in Mawlamyine, in addition to the existing 'informal' recycling system. As described before, there is already a thriving informal sector for recyclables collection.

Figure 3-32: Recycling Supply Chain



(Source: Adapted from Marchand 1998)

To keep this sector active and increase the amount of recycling materials, the following measures shown in Table 3-16 are proposed.

Table 3-16: Proposed Recycling Improvement actions

Collection	Weaknesses	Action required
Informal collection of recyclables	Works good at the moment and at no costs for the township, however public is not actively participating and health risk for collectors	Public awareness promotion for recycling and providing sanitary health & safety equipment for the informal sector
Formal collection of recyclables	At the moment not present	Introducing at schools, township offices and other official buildings separation in 3 different (colour) containers for: a) recyclables ("dry waste") b) compost ("wet waste") c) remaining fractions

Micro - and small recycling businesses buy materials that have been extracted from waste containers, collected from households or bought from businesses. They sell these to medium and large recyclers, called 'dealers' or 'traders', who, in turn sell them to end-user industries.

3.3.7 COMPOSTING

At the moment there are no composting activities in the project town. To implement composting, the following options are proposed.

Table 3-17: Proposed Composting Actions

Options	Action Required
Backyard composting in the peri-urban areas of the town and for houses with large gardens	Introduce Instruction and Awareness Programs for backyard composting Introduce incentives for lower collection fees for those households participating (they generate less volume of waste to be collected!).
Composting facility at the location of dumpsites/landfills	Implementation of a Composting Plant with extension options for future capacity growth (modular system). This can be done in combination of upgrading existing landfills or construction of new landfills (see next paragraph)

Composting will be a major achievement in the Municipal Integrated Solid waste Management System. A detailed description of composting and composting Plant is provided in the next section with several options analysed and presenting the best option selected.

"One of the most promising solutions for Waste Reduction"

3.3.8 SOLID WASTE TREATMENT AND DISPOSAL

GENERAL ISSUES

With a new sanitary waste treatment and disposal site, it is almost certain that disposal costs will rise. This is more than a municipality generally can afford, and this means that closure of a local landfill in many cases lead to regionalization of disposal sites.

Regionalization requires new institutions to manage it, and these new institutions require financial tools and a basis on which to raise investment funds and manage operational costs.

A regional landfill treatment and disposal will serve a larger number of municipalities with different political colours and so has a risk of creating conflicts of interest of a political and/or financial nature. Questions and conflicts arise like who is responsible for the landfill, and how is it paid for.

Also there is lots of room for conflict about where the landfill will be sited, and resolving this conflict can cost a great deal of time.

Although regionalization of landfill sites is in many cases the best economical option (economies of scale), this is not further considered feasible for this project implementation.

SOLID WASTE TREATMENT OPTIONS AND WTE

In general there are three main Municipal Solid Waste treatment options:

- Incineration with WtE (Waste to Energy);
- composting and landfilling combination;
- landfilling with biogas production from mixed waste and energy production (WtE, Waste to Energy).

A general description of these 3 main disposal options is given in Table 3-18.

Table 3-18: Main Solid Waste Disposal Options

	Technology	Description	Remarks
1	Incineration and WtE (Waste to Energy)	The waste in developing countries, particularly in South Asia, is characterized by a significantly higher density and moisture, mainly organic waste with low caloric values (700–1,000 kilocalories). Given these physical and chemical characteristics of waste in the region, incineration - which is ideal for dry matter with high caloric value - is not a suitable option. In 1987, for example, a 300 tons/day incineration plant was established in Timarpur, Delhi. The project, which was expected to produce 3.75 megawatts (MW), failed, and ultimately shut down in 1990 due to the high volume of refuse with low caloric value. Incinerators require sophisticated flue gas treatment, which are expensive and require intense operation &maintenance and continuous air quality controls.	The South Asian Association for Regional Cooperation (SAARC) Dhaka Recommendation on Waste Management (October 2004) agreed that incineration, as well as unproven technologies such as plasma, should not be considered as an option for the treatment of Municipal Solid Waste of low caloric value and high environmental pollution potential. Another disadvantage is the high investment costs and high operational costs. Further high skilled operators are required for the daily operations.
2	Composting of Organics and landfilling of remaining rejects	The organic component of municipal waste generated in developing countries is greater than in developed economies, comprising well over 50% in these countries. In that context, biological treatment, composting in particular, can help recover and transform organic waste into soil conditioners and fertilisers. These processes reduce GHG emissions by sequestering biogenic carbon in the soil, improving its physical properties, adding nutrients, and reducing the need for pesticides.	Biological treatment and recycling of this bulk organic fraction at a lower cost makes these methods a more suitable option for developing municipal economies in South Asia. A (smaller) landfill is still required for proper disposal of the remaining waste fractions.
3	Landfilling with Biogas production and WtE (Waste to Energy)	Engineered landfill, rather than open dumping, also contributes to Green House Gas mitigation. Landfilling refers to disposal sites where waste is placed in lined sections, where it degrades while producing biogas; CO2 and methane with further possibilities for energy recovery. Landfill processes can be controlled in order to stimulate the biogas reactor. The main output of a modern landfill system is electricity production from the combustion of biogas, with an average energy efficiency of 35%.	Many of the landfill-related Biogas projects are less ambitious; they are offering controlled flaring rather than the utilisation of energy potential. This is especially the case with smaller sized landfills, like to be implemented in Mawlamyine. Further a landfill Gas-to-Electricity Plant has to be constructed with large Gasholders, which means

		The CDM (Clean Development Mechanism; introduced under the Kyoto protocol) enables countries, to invest in emission-reduction projects in developing countries and to use the associated emission-reduction credits towards achieving their own targets, as a supplement to their domestic GHG reduction actions	high investment costs and high skilled operators required. The electricity produced should be sellable to a third party, the electricity company, which requires intense communication with the company and secure connection to the network.

CONCLUSION

- Option 1: As presented above, Incineration is not being appropriate for the project Towns project and is not further considered an option for this project.
- Option 3: Landfilling with Biogas production: this option is not further considered feasible to the fact that the size/capacity of the projected landfill is too small for generation enough biogas for economical electricity generation, which means the biogas has to be flared on-site without any revenues.
- Option 2: Composting of Organics with landfilling of remaining rejects is the best option for the 3 project towns. Also the SAARC countries (South Asian Association for Regional Cooperation) agree to encourage establishing community-based segregation at source, separate collection, and resource recovery from wastes with particular focus on composting.

Recommendation:

"Implementation of a Composting Plant with a final Controlled Landfill for the remaining rejects". The following sections will describe the Composting Plant and the Controlled landfill in more detail.

3.3.9 COMPOSTING PLANT

INTRODUCTION TO COMPOSTING

The physical composition of solid waste of the developing countries consists mostly of organic matter, which is biodegradable. To reduce reliance on landfill as a disposal route, biological treatment is increasingly becoming adopted as a standard requirement for the vast majority of biodegradable wastes.

Controlled Composting differs significantly from the decay process that occurs in nature; it is monitored and controlled, aerobic conditions are maintained, and it includes a high-temperature phase (e.g., above 55 degrees Celsius [°C]) that reduces or eliminates pathogens and weed seeds. Conversion rate per ton of organic waste to compost is approx. 25%.

Climate is a natural force which may cause failure of a composting project (e.g. by heavy rainfall saturating the composting windrows). Such climatic condition may pose a threat, which means adjusting the technology e.g. by roofing the composting site and providing a drainage system.

The major aim of composting is to achieve benefits for the entire solid waste management system by improved landfill management and reduced quantities of waste to be disposed of at the landfill.

Another effect is much lower emission of methane which is a major greenhouse gas due to anaerobic condition in the dump sites.

Many factors influence which organic waste collection programs and processing technologies should be implemented, a/o the community's waste diversion targets, the desired level of convenience for the users, processing facility site location, commitments to greenhouse gas (GHG) reductions, and costs.

The importance of these factors helps to determine which technologies are most appropriate, such as a separate collection system, which composting technology system e.g. aerobic system or an anaerobic digestion (AD) system, or a combination of both.

Determining the size of the processing facility is another key consideration, which is heavily dependent on the types and quantities of compostable materials (feedstocks) diverted through the collection program, as well as the location of the proposed processing facility.

Backyard Composting: It is not expected that a large volume of organics will be diverted from this waste streams, however every m3 which has not to be collected, is less collection required for the municipality.

GREENHOUSE GAS (GHG)

When mixed municipal solid waste (MSW) is sent to a landfill, the organic matter generates greenhouse gas (GHG) emissions. Anaerobic decay of these materials in a landfill leads to the generation of methane, which in turn is released to the atmosphere if there are no controls in place.

GHG reductions can be realized when organic waste is diverted from landfills to composting or Anaerobic Digesting (AD) facilities and processed under controlled conditions. MSW organics buried in a landfill break down anaerobically and produce landfill gas that consists primarily of methane (CH_4). Methane is a potent GHG, with approximately 25 times the global warming potential of carbon dioxide (CO_2), making landfills a significant contributor to GHG emissions. Methane also has a relatively short atmospheric lifetime (of about a decade), as compared to carbon dioxide (which remains in the atmosphere for centuries). Due to this short atmospheric lifetime, reducing emissions of methane and other "short-lived climate forcers" has the ability to slow the rate of near-term climate change.

The environmental benefits of diverting organic materials from landfill include reduced methane emissions (a potent greenhouse gas), and decreased leachate quantities from landfills.

Recycling organic matter to the soil is a part of carbon cycling, an emerging and important environmental issue. Organic waste is recognized as an important organic matter resource and has numerous beneficial attributes.

Diverting one ton of food waste through composting or anaerobic digestion reduces GHG emissions by approximately one ton of CO_2 equivalent compared to landfilling.

SOURCE SEPARATION ORGANICS (SSO)

The successful diversion of biodegradable wastes from landfill relies on the separation of these wastes at source. Whilst the biodegradable fraction can be extracted from mixed wastes, this is laborious and produces a contaminated product. Separation at source offers the opportunity of a high-quality clean feedstock for composting and the prospect of an uncontaminated product.

The most labour-intensive and tedious task of the composting process is waste separation. It can be facilitated if households of the community agree to segregate the waste, putting biodegradable (or "wet") waste into a different container from the one used for other wastes. If at-source segregation is being considered, this will require an intensive publicity and follow-up campaign in order to achieve a satisfactory degree of segregation.

A very intensive publicity campaign involves meetings with householders, presentations in the wards, campaigns in schools and public offices, and advertisements in newspapers and on television and radio. Composting schemes tend to be popular with the local population, creating jobs and a 'feel-good' factor. Publicity campaigns promoting the scheme can emphasise these key points.

The following three activities will raise the awareness of the community:

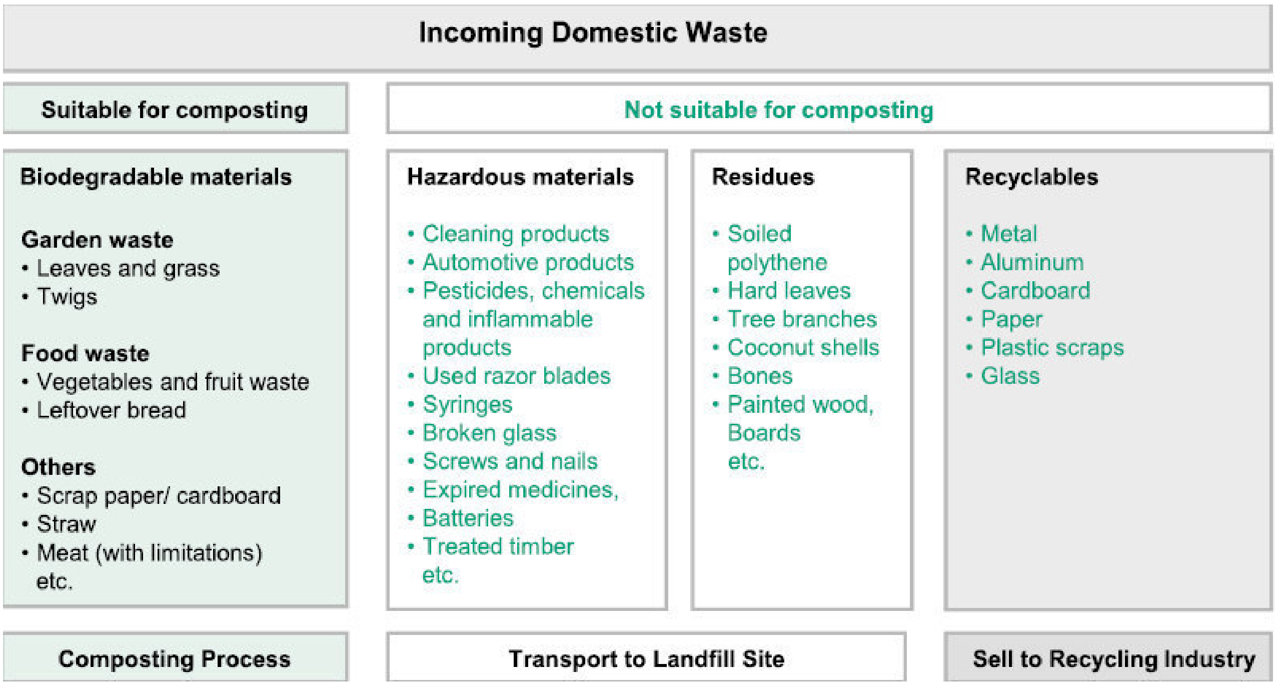
- Prepare and distribute leaflets among the households describing the benefits of source segregation and guidelines helping residents to differentiate between inorganic and organic waste;
- Affix posters with basic information to the collection trucks;
- Organise open-house events, inviting the community to the composting plant. Explain on site why source segregation greatly contributes to enhancing the operation of the composting plant.

If households are willing to segregate their waste at source it saves a tremendous amount of time and costs for the composting scheme. Moreover, it increases the quality of both biodegradable waste and recyclables.

Hence, the main goal should be the introduction of source segregation of waste in households. Residential source-separated compost programs, which include food scraps, soiled paper, and yard trimmings, are well established and successful in many countries around the world.

The separation of municipal solid waste is shown in Figure 3-33.

Figure 3-33: Source Separation of Municipal Waste



Source: Sandec composting organic waste 2006

COMMUNITY COLLECTION SITES

Source segregation can be achieved by the municipality to provide several smaller drop-off sites located at a neighbourhood level throughout the community. This allows sites to be located closer to waste generators, making them more convenient to use. Theoretically, the higher level of convenience results in higher participation rate and a greater diversion rate.

These neighbourhood sites typically consist of waste container, such as 2 to 4 m^3 commercial waste containers. The collection containers must be animal-and insect proof because of the food waste included. A typical container is shown located in Figure 3-34.

Figure 3-34: Containers for Source Separation of Organics

The containers must be emptied frequently (e.g., two to three times per week) to prevent them from overflowing and becoming unsightly, and to prevent odours.

Depending upon the style of container, community depot sites can be located at municipal facilities (e.g., parks, sports fields, parking areas) or at the sides of roads with appropriate shoulders for safe access.

KERBSIDE COLLECTION PROGRAMS

Kerbside collection of organic waste from residential sources can significantly increase diversion rates by making the service more convenient; thus, increasing program participation and capture rates. In established programs with regular weekly service, consistent participation rates of 80 to 90%, and diversion rates of 75%, are achievable.

Although kerbside programs can increase diversion rates, they come at a substantially higher cost than maintaining and operating community collection sites. Costs for kerbside collection programs vary depending on the frequency of collection, the number of households, and the distance to/from processing facilities.

There are also variations in the type of trucks that are used for kerbside programs: single-compartment versus dual-compartment trucks, and manually loaded trucks versus trucks with automated lift arms. The choice of truck depends on collection schedules and frequency, what materials are being collected, and the destination of the materials. Also these trucks are more expensive than normal collection trucks.

CART-BINS BASED COLLECTION PROGRAMS

Collection of organic wastes, garbage, and recyclables using standardized, wheeled carts is becoming more commonplace.

Cart-based collection programs for organics eliminate many of the problems associated with plastic-bag-based collection, and when combined with automated or semi-automated collection trucks, allow for increased collection productivity.

Bins for organics are available in a number of sizes, ranging from 50 to 360 litres (L). Popular bin sizes used in organics collection programs are 120, 240, and 360 L. Smaller bins (i.e. 50 and 80 L) can be collected manually. Larger bins require the use of automated or semi-automated lifting arms on the collection truck. A 240 L waste bin I shown in Figure 3-35.

Figure 3-35: Typical 240 litre collection waste bin

RECOMMENDATION

In the town the existing house-to-house collection and the bell ringing system is working relative appropriate. To improve the system for separate collection of organics the options mentioned before are compared in the Table 3-19 with the advantages and disadvantages of each collection system.

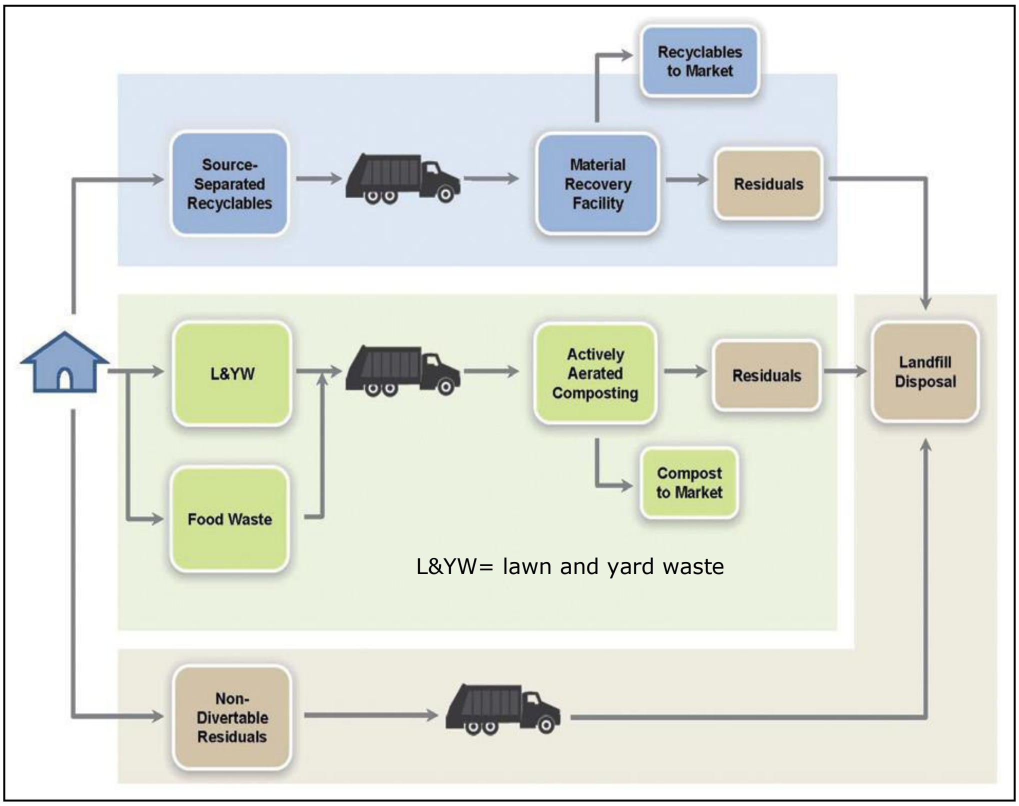
Table 3-19: Option Analyses SSO collection systems

System	Advantages	Disadvantages
Community collection sites	Simple to implement Easy for population to divert their waste Low investment costs Easy for collection trucks	Population has to be acquainted with bringing their waste to these points Keep the area clean is important as people spoil waste next to the containers
Kerb-side collection	High separation rate Convenient for the population	High investment cost due to special trucks and large amount of waste bins
Card-bins based collection system	High separation rate Convenient for the population	High investment cost due to special trucks and large amount of waste bins

The options 2 and 3 are more expensive, difficult to implement without large public awareness campaigns and requires also shifting of the cleansing department collectors. Therefore it is recommended to implement option 1: community collection sites in the town; it is the less costly option, simple to implement and can easily be further improved over the years as the population will get acquainted with source separation.

In order to reduce the costs of long distance transport, the waste will be transferred from the collection vehicles into large container trucks, located at different areas of the town, the Transfer Stations. These large container trucks carry the waste to the composting plant and landfill as shown in Figure 3-36.

Figure 3-36: Collection and Transport in SSO Waste System



COMPOSTING PLANT

Introduction

A composting plant comprises an operation area and a "green" buffer zone. The buffer zone, formed by a belt of bushes and trees surrounding the operation area, improves the visual appearance of the composting plant and the adjacent landfill area.

The operation area is divided into different zones. It contains space for waste unloading and sorting, composting, maturing, sieving and bagging of the compost, including storage space for compost. These zones must be arranged so as to ensure efficient workflow of the composting process. Additional space should be allocated for an office and sanitary facilities for the workers.

On-site water supply is a basic infrastructural requirement on a composting site. Since it is used for hygienic purposes and for watering the compost heaps, a reliable water supply should be ensured. Sanitary installations, such as toilets and washing facilities, are essential. After handling waste and compost, the workers should wash and change their clothes before leaving the workplace.

Composting operations should be conducted under a roof to protect the compost piles from excessive rain and sun. Simple light structures with steel – or concrete supporting poles can be used to support the roof.

The sorting area consists of a sealed concrete surface where the waste is sorted into organics, inorganic recyclables and rejects. The sealed surface facilitates cleaning after sorting is completed. Since the waste delivered may be high in moisture, the area should be slightly sloped (1%) to avoid leachate ponding. A drainage system collects leachate and cleaning water to be reused for watering the compost.

Conveyor belts are installed and operated for internal transport of the organics streams.

Rejects will be disposed of at the adjacent landfill and recyclables (small amount because most are already removed from the waste before) will be stored in a separate area to be collected by the recycle companies.

Electricity supply is essential preferable 3-Phased 380V. An energy-efficient lighting system should be fitted to set a good example of energy conservation and to reduce operational costs.

The roads for waste delivery and pickup of residues should be well maintained and easily accessible throughout the year.

It is recommended to employ the today's waste pickers from the existing dumpsite at the composting facility.

Processing Technologies

A number of technologies and techniques have been developed and refined, ranging from simple and inexpensive, to complex, highly mechanized, and automated solutions.

First there are two distinctive technologies:

- I: Aerobic Process; further subdivided into two options:
  - A) Passively aerated
  - B) Actively aerated
- II: Anaerobic Digestion (AD) Process

The following considerations are given is selecting the best option for source separated organics treatment in Mawlamyine:

- Separated Organic waste includes leaves, yard waste (L&YW), and food waste ("wet" waste);
- Excluded is the option with "co-digesting" in anaerobic digestion system of a Waste Water Treatment Plant (WWTP); at the moment there is no WWTP in the three towns;
- Technology II: Anaerobic Digestion (AD) of Source-Separated Organics (SSO) from the municipal solid waste (MSW) stream is a relatively new technology. It is a very sophisticated technology with special expertise required. Systems as "high solids stackable", or "high solids slurry" and "liquid wet low solids" systems are already in use, however with high investment and operational costs and the need of highly skilled operators. The "AD" option is not further considered for the three towns (only applicable if it will be a DBO-project (Design-Build-Operate) by third parties if interested).
- The focus should not be on energy electricity production (too small quantities available, small plants), but main outcome should be high quality compost.

Following the considerations mentioned above, Technology I, Aerobic Processes, both A) Passively aerated, and B) Actively aerated, will be further investigated to select the best option for Mawlamyine. Table 3-20 provides an overview of the available techniques of composting systems.

Table 3-20: Proposed Composting Techniques to be further analysed

Passively aerated	Actively aerated
Static pile	Aerated static pile (ASP)

Bunker	Enclosed ASP tunnels
Windrow	Containerized ASP
Turned mass bed	Channel
Passively Aerated Windrow (PAW)	Agitated bed
	Rotating drum

The following section and Table 3-21 provides a brief overview of the composting methods and technologies outlined in Table above. These are suitable for facilities with capacities ranging from a few hundred tonnes to tens of thousands of tonnes per year (tpy).

Table 3-21: Overview Passive Aeration Composting Techniques

	Static piles	Bunkers	Windrows	Turned mass bed	PAW
Typical capacity tpy	< 10,000	< 5,000	< 50,000	15,000 to 50,000	< 10,000
Food waste included	no	no	yes	yes	yes
Typical active composting time	2 to 3 years	2 – 6 weeks	3 – 12 months	3 – 12 months	1 – 2 years
Post processing process	curing	curing	curing	curing	curing
Relative space requirements	High	Medium to high	Medium to high	Medium to high	high
Fuel consumption equipment	Low to medium	Low to medium	high	high	Low to medium
Leachate quantity	low	low	low	low	low
Construction cost	low	low	Low to medium	Low to medium	low
O&M cost	low	low	Low to medium	Low to medium	low

From the above table it can be concluded:

- Composting time longer than 1 year is not feasible: this eliminates two options 'static piles' and PAW (passive aerated windrows);
- Food waste composting when not included is not feasible: this eliminates two options: 'static piles' and 'bunkers';

- Capacities less than 10,000 tpy are not feasible, especially for the longer term with extension and higher quantities; capacity should be above 10,000 tpy, which means elimination of options of 'static piles', and 'bunkers' and 'PAW'.

Remaining two options with passively aeration technology: 'windrows' and 'turned mass bed'. However these options require still long active composting times, 3 to 12 months, which means consequently large surface areas should be available.

Actively aerated technologies have significantly shorter active composting times than passively aerated systems and consequently require less surface areas.

The "actively aeration technologies" are shown in Table 3-22.

Table 3-22: Overview Active Aeration Composting Techniques

	ASP (positive aeration)	ASP (covered)	Tunnel system (=enclosed ASP)	In-Vessel System	Channel	Rotating drum
Typical capacity (tpy SSO)	1 000 to greater than 100,000	1 000 to greater than 100,000	10 000 to greater than 100,000	500 to 50,000	15 000 to 100,000	1 000 to greater than 100,000
Typical active composting time	2 to 6 weeks	3 to 8 weeks	2 to 4 weeks	2 to 4 weeks	2 to 4 weeks	2 days to 1 week
Aeration method	Aeration fans	Aeration fans	Aeration fans	Aeration blowers, aeration lances	Aeration fans and mechanical agitation	Aeration fans and mechanical agitation
Post processing requirements	Curing	Curing	Curing	Curing	Curing	Further Composting and curing
Relative space requirements	Low to medium	Low to medium	Low	Low	Low to medium	Medium to high
Electricity consumption	Medium	Low to Medium	Medium	Medium	Medium to High	High
Leachate/condensate quantity	Low	Low to medium	Medium	Medium	Low	Low
Construction cost	Medium	Medium	High	Medium to High	Medium to High	High
O&M cost	Low to medium	Low	Medium to High	Medium to High	Medium	Medium to High

Note: ASP= Aerated Static Piles

From above table it can be concluded:

- Composting time all within a range no longer than 8 weeks maximum, however the option of a "Rotating drum" requires additional composting and curing time;
- For cost comparison, two options "Tunnel System (enclosed ASP)", and "Rotating drum" have higher construction costs and medium to high O&M Costs.
- ASP systems (Aerated Static Piles) are very flexible to future changes in capacities tpy, easy extension possible when area is available;
- Further details for 1) Aerated Static Piles ASP (positively aeration), and 2) ASP (covered), 3) "In-Vessel System" and 4) "Channel' will be compared below to obtain the best option.

Four options will be described below:

- Aerated Static Piles ASP (positive aeration);
- Aerated Static Piles ASP (covered);
- In-Vessel System;
- Channel composting system.

Ad 1) Aerated Static Piles ASP (positive aeration)

Aerated static pile: compostable materials are placed in large piles which are aerated by drawing air through the pile or forcing air out through the pile.

The advantages and disadvantages of the ASP system are shown in Table 3-23.

Table 3-23: Aerated Static Piles advantages and disadvantages

Advantages	Disadvantages
Pile configurations and height result in reduced space requirements	Slightly higher capital cost for forced-aeration equipment
Use of negative aeration can help avoid odour problems	Over-aeration can remove moisture
Smaller surface area relative to windrows reduces impacts of weather and rain infiltration	Feedstock pre-processing requires a higher degree of care; feedstocks must be well mixed and properly sized and moistened
Significantly shorter active composting times than passively aerated systems	More operator skill required to manage aeration systems
	Aeration systems generally require three-phase electrical supply

Ad 2) Aerated Static Piles ASP 'covered'

The difference with "ASP covered" system with "ASP positive aeration" is the tarp covers installed over the piles. The tarp covers generally protect the pile from infiltration of precipitation, reduce evaporative loss of water from the compost pile, reduce vector attraction, and in some cases help to control odours and volatile organic compound emissions.

Covered ASP systems are usually designed with an active composting time of three to eight weeks.

Feedstocks are injected into tubes as they are unrolled using a special piece of equipment that also places one or two flexible plastic aeration pipes in the bottom of tubes. When the pods are filled, the ends are sealed, and the pipe(s) in the base are connected to a positive aeration system. When the composting is complete, the plastic tubes are cut open, and the materials are removed.

This option 2 is essentially an upgrade system from option 1, it is possible to start with installation of option 1 and upgrade later to the option 2. However, option 2 is more labour intensive and therefore needs more staff and extra costs for the tarp covers with regular replacement (higher OPEX).

Ad 3) In-Vessel system

In-vessel composting occurs within a contained vessel, enabling the operator to maintain closer control over the process in comparison with other composting methods.

In-vessel in "vertical plug-flow" systems, the bio solids and bulking agent mixture is introduced into the top of the reactor vessel and compost is discharged out the bottom by a horizontally rotating screw auger.

Air is introduced in these systems either from the bottom and travels up through the composting mass where it is collected for treatment or through lances hanging from the top of the reactor.

In-vessel technology is more suitable than other composting technologies in suburban and urban settings because the system allows for containment and treatment of air to remove odours before release.

The requirement for a relatively small amount of land also increases its applicability in these settings over other types of composting. In-vessel requires less land area but higher investment and operation costs (vessel maintenance, regular replacement of rotating screw augers, more obstructions with the aeration system) than other actively aeration technologies.

The advantages and disadvantages of the In-Vessel system are shown in Table 3-24.

Table 3-24: In Vessel Composting advantages and disadvantages

Advantages	Disadvantages
Relative small area required for the vessels	Higher capital cost for vessels construction, mechanical parts and forced-aeration equipment
aeration releases can easily be captured and treated	feedstocks must be well mixed and properly sized and moistened
Very limited impacts of hot weather and (monsoon)rains infiltration	Rotating screw auger required regular maintenance and replacement, higher maintenance costs
	More operator skill required to manage the system

Advantages	Disadvantages
	Aeration systems generally require three-phase electrical supply

Ad 4) Channel composting system

Channel systems are essentially turned windrow piles placed inside of buildings. The windrow is situated between two long, parallel, concrete walls that are 1.8- to 2.4-m high and spaced between 3- and 6-m apart.

For Channel composting system, a specific turning machine is required.

A turning machine rides along the tops of the concrete walls. The turning machine has a conveyor or rotating drum that hangs below it and physically lifts and throws the compost backwards, agitating it in the process. As the turning mechanism makes repeated passes down the channel over time, it moves the mass of material from the feed end of the channel to its discharge end.

This specific turning machine needs experienced operators. Also it has high investment and O&M costs.

The advantages and disadvantages of the Channel system are shown in Table 3-25.

Table 3-25: Channel Composting advantages and disadvantages

Advantages	Disadvantages
Usually enclosed in buildings, so a higher degree of odour control can be achieved	Medium to high capital costs
Less space required than windrow composting	Lacks flexibility in dealing with feedstock peaks(requires increasing the turning schedule)
Mechanical turning systems are elevated above the composting bed and are easier to maintain	Positive aeration results in lower indoor air quality
	Proper preparation and mixing of feedstocks and amendments is critical
	Building and facility footprints are long and narrow, which may not fit on some properties

CONCLUSION

The channel composting system is more prone to failures and has higher investment cost and O&M cost than the ASP systems. The In-Vessel system has higher investment costs and need higher skilled operators and requires more maintenance. The "ASP covered" system can still be implemented if this seems necessary when an "Aerated Static Piles ASP (positive aeration)" system has been installed.

The recommended option for composting system, taken into account the investment costs, the O&M costs, the simplicity of operation, the duration of the composting time and the available land area is the "Aerated Static Piles ASP (positive aeration)" system.

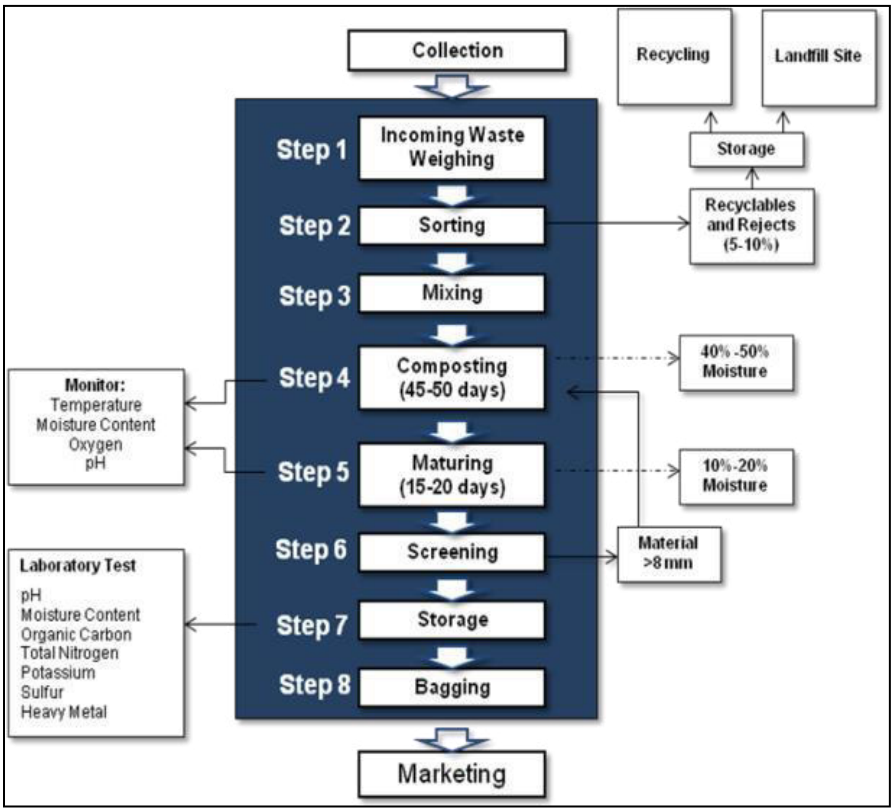
DESCRIPTION OF AERATED STATIC PILES (ASP) SYSTEM

In this technology, as shown in Figure 3-37 food waste organics and lawn–and yard waste, are collected together via the Community Collection Sites program. The materials are delivered by the transfer trucks to the composting facility where they are composted.

In the aerated static pile design option, the incoming organic stream is first pre-processed. After pre-processing, piles will be formed using a front-end loader.

The aerated static pile design option assumes, as a default, that a grid of piping lies out beneath the pre-processed stream to aerate the pile. Through blowers, sufficient air is supplied to the composting pad to aid the mixing, temperature control, and water vapour control. Finally, a layer of screened compost is often placed on top of the newly formed pile for insulation and odour control.

Figure 3-37: Flow Chart composting process and material flows



The organic wastes are delivered to the composting centre as shown in Figure 3-38. In the facility, paper and cardboard which are not already recycled, are composted in addition to kitchen and garden wastes. The composting operation can be divided into five main stages:

- **Delivery:** compostable wastes collected from the town green are delivered by transfer truck;
- **Sorting:** the sorting of waste through screening is to remove contaminants using equipment such as a trommel screens. Waste is forced into the trommel screen and separated into different size fractions and contaminants such as plastic films will be removed. A conveyor belt transport the screening further while other contaminant will be removed by handpicking (glass, plastic, etc.); further metallic wastes are removed using a magnetic separator above the conveyor belt. Then the wastes pass through a rotating 20 mm meshed screen in order to eliminate undesirable and coarse elements;

- **Mixing / Crushing:** the wastes are crushed and mixed before being conveyed to the composting pad;
- **Composting:** the organic wastes are put in the windrows, an air canal supplied by a ventilator diffuses air according to the windrow temperature in order to accelerate the composting process;
- **Maturing:** this operation lasts for about one month. The compost continues to mature until its biological activity has stabilized.

Figure 3-38: Organics loaded with Front-end loader

Maturing / Curing

Curing is an often neglected stage in the composting process. This final stage prevents the use of immature compost by allowing the compost to mature until stable. Curing occurs at lower temperatures, consumes less oxygen, generates less heat, and reduces moisture evaporation. This stage continues the aerobic decomposition of resistant compounds, organic acids and large particles, increases the concentration of humus, and allows the compost to gain disease suppression qualities (Rynk, 1992). Immature compost is an undesirable end product because it continues to consume oxygen, contains high levels of organic acids, possesses a high C/N ratio, competes for nitrogen, and can damage plant growth when used for agricultural applications.

Final Conditioning / Screening

Screening improves the final quality and appearance of the mature compost. Mechanical screening is an effective way to remove unwanted objects, recover bulking agents, and separate organics that are not completely decomposed. Screening also provides different "grades" of compost based on the particle size; coarse compost is usually returned back to the process to be further refined.

AREA DESCRIPTION

The composting area is preferably a concrete slab slightly sloped (1%) towards one side to allow excessive water from the compost heaps to flow into a drain. Along the lower end of the slab, a drainage channel for leachate collection leads to a collection point.

To operate efficiently, a composting facility must allot sufficient space to the pre-processing, processing, and post-processing compost stages as well as to the surrounding buffer zone. Typically, the bulk of the site will be occupied by the composting pad and storage area.

The total facility area comprises a tipping floor, pre-treatment area (for trommeling and shredding), composting pad, curing area, buffer zone, offices, roads, and storage of compost material and equipment.

Tipping Floor

The tipping floor design is based on an average waste height of 3.0 m, a maximum retention (storage) time of 4 a 5 days, and a manoeuvrability factor of 2.5 for a front-end loader. The tipping floor area requirements are calculated based on the daily flow rate (in tpd) and the bulk densities of each component entering the tipping floor.

Composting Pad

This is the area required for the composting and turning of organic waste compost piles. The composting pad is the largest area of the facility and the design is based on the typical geometry of the piles when regularly turned by a front-end loader. The following Design guidelines are used: provision for equipment turning clearance (manoeuvrability factor of 2.5), space between windrows (min. 2.0 m), side clearance (min. 2.0 m), windrow height (approx. 3.50 m), windrow base (max. 10.0 m), windrow crown (approx. 0.6 m), and windrows in parallel.

The organics are mixed and piled. There is no standard width or length for ASPs, as size is often dependent on site-specific requirements and land availability. For aerated static pile composting, pile dimensions can be for example:

Base width: 3.0 m - 6.0 m, Height: 1.5 m - 3.5 m, Length: 30.0 m or more.

In an actively aerated composting system, the air is distributed through the composting pile by a network of air pipes underneath the composting pile. The simplest method is a pipe-on-grade system using a set of perforated pipes that are laid out on the ground, with the compost pile built on top of the pipe system. The perforated pipe is often covered by a porous layer of woodchips or straw before the compost pile is built to improve air distribution. The perforated pipes and the porous base layer should typically be at least 2 m from the edges of the pile to prevent air from short-circuiting out the ends and sides of the pile, and to force air to pass through the material being composted, as shown in Figure 3-39.

There are several variations of in-floor systems, including covered trenches, pipe and spigot arrangements. These systems are more costly to construct but allow for quicker pile construction and tear-down, since there are no exposed pipes. They also eliminate the risk of damaging aeration piping and the need to replace pipes. Often, below-grade systems provide more efficient air delivery, which translates to reduced electrical consumption by aeration fans.

Fans are usually of the centrifugal-axial-blade type. The size of the fan or blower depends on a number of factors, including the type and porosity of material in the pile, the size of the pile, and air flow characteristics of the air distribution system.

Figure 3-39: Example outdoor composting with aeration pipes system

Leachate Flows: Generally, no significant amounts of leachate are produced in composting facilities, as long as compost is covered and the moisture content is kept near optimal values.

Wastewater reuse system: wastewater is generated during composting and the cleaning of the facility. Instead of discharging the wastewater into drains, it can be reused for new compost piles to maintain the moisture balance and enhance the decomposition process.

Front-end loader manoeuvrability factor for turning of piles; default of 2.5 is used

The following residence times will be used as default during ASP composting and curing stages of the waste stream:

For the high quality compost a 51-day compost residence time with a curing period of 30 days.

Maturing or Curing Area

At facilities that use the ASP composting system, curing activities normally take place in a separate, outdoor area. The curing areas should be located up-slope so that drainage from receiving and active processing areas does not flow into or through the curing area as shown in Figure 3-40. Curing pads should also have a slope of between 0.5 and 2% to promote drainage.

Normally curing takes place in open air windrows. However, during the monsoon rains in Myanmar it is recommended to cover the windrows with a simple roofing to avoid excessive rainwater intrusion and for the hot season to avoid too much evaporation.

The area for the curing piles is designed for a 30 days maximum storage period. The curing area needs less space compared to the composting area, about one quarter of the area of the compost pad.

Finished Compost Storage Area

Finished compost should be stored away from operating areas so that it is not contaminated by incoming feedstocks or surface water runoff from active composting and curing pads.

The treatment (for shredding and screening) and equipment storage areas were designed based on a typical footprint area of all pertinent equipment, the number of units, and a manoeuvrability factor of 2.

Area for storage of finished product: the size should take into account a storage period of ready product of max. 4 months.

The storage area should have graded surfaces (e.g., sloped at 0.5 to 2%) that promote drainage and prevent water from ponding, which can raise the product's moisture content (and affect sales efforts) and/or result in anaerobic conditions and odours.

Figure 3-40: Windrow Layout in Curing Pad

The product storage area should also have a working surface consisting of a strong sub-base and base material that is able to support the weight of wheel loaders and trucks without rutting.

The size of product storage areas is a key consideration and is normally determined by the facility's production cycle and the demand for compost over the year.

For the surface calculation of finished compost area the following theoretical volume calculations is used (based on experiences in other countries): for every tonne of source-separated organics that is composted, approximately 0.5 tonnes of finished compost is produced.

A large volume of reject material, - about 20 % of incoming materials -, is rejected and sent to the landfill. This material may however be used as daily covering material of the waste at the landfill-front in the Cells.

Other Area Requirements

An office, sanitary buildings, repair shop and equipment parking are required.

Finally, the buffer zone is indicated with a distance of 10m from the fence/ land property area border, as shown in Figure 3-41.

A typical hangar type roof required for monsoon rains protection is shown in Figure 3-42.

Figure 3-41: Generic Lay-out of Composting Plant Mawlamyine

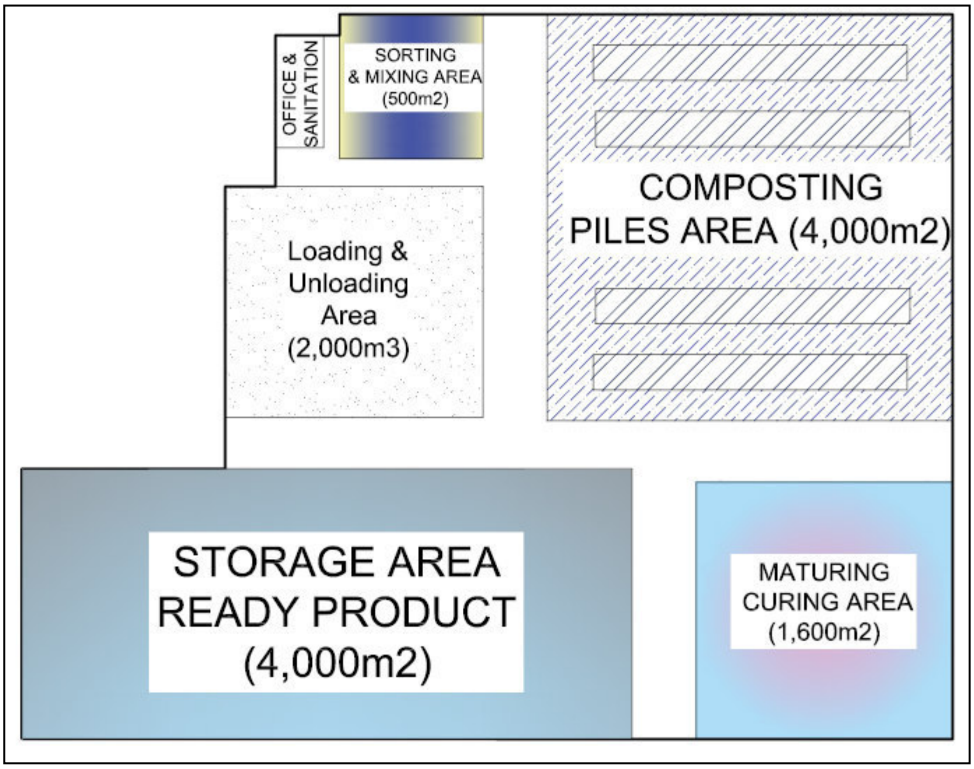
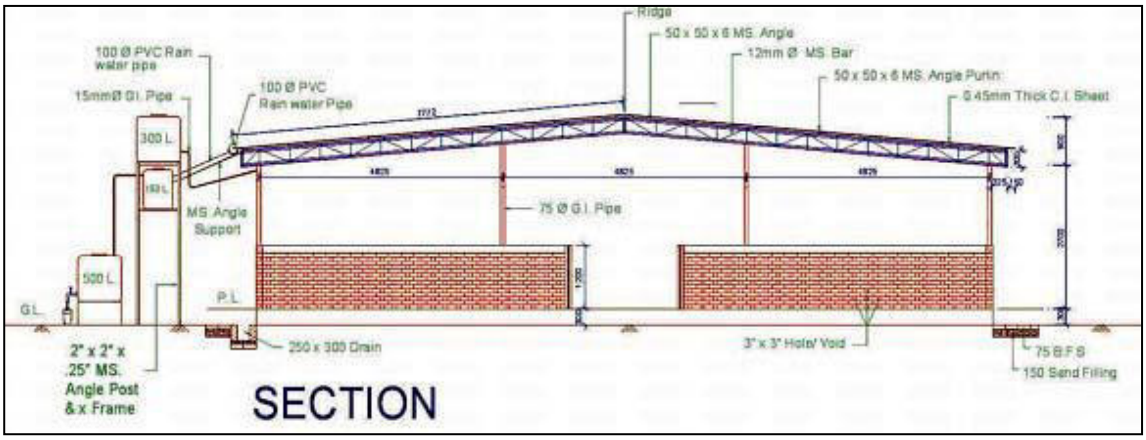


Figure 3-42: Example of Compost Cover: Hangar Type Roof



3.3.10 DISPOSAL LANDFILL

INTRODUCTION

A controlled landfill is a carefully engineered area specially built for environmentally safe disposal of wastes. The aim is to avoid any hydraulic (water-related) connection between the wastes and the surrounding environment, particularly groundwater.

A controlled landfill requires a very large area, due to the fact that it should have a life span of minimal 25 years uninterrupted disposal of municipal waste and the environmental requirements like protection of the groundwater and distances to rivers, creeks and other water courses. Next to this in the surrounding of a sanitary landfill no housing settlements are allowed because of health risks and nuisance.

UPGRADING OF EXISTING DUMPSITE

In Mawlamyine the existing dumpsite is about 2.5 ha in a 38 ha public area, large enough to upgrade this site to an environmental safe sanitary landfill site. Also the site is already in ownership of the Government which is favourable than to purchase new land elsewhere (which is difficult to find in short term, especially due to the large size and required buffer zone). The site is far enough from town, about 10 km and there are no housing in the surrounding areas. However, during implementation of this PPTA project, in December 2015 MSG started building apartment blocks at a distance of 300 m from the landfill site boundary. Conform the EPA (Environmental Protection Agency) International Regulations, a distance of 500 m should be used as Buffer Zone (see Box next page); however the Government of Myanmar has no regulations set for this area but it is foreseen that they will follow these Environmental regulation in the near future. It is highly recommended to stop further more apartment constructions in the dedicated Buffer Zone.

Minimum buffer distances at municipal solid waste and general waste landfill facilities:

- 500 m to residential development, rural townships and highways or arterial road networks.
- A lesser buffer may be acceptable where it is considered compatible with the surrounding area and land uses so that there will be an effective buffer of 500 m between the landfill and any sensitive or incompatible land use.

To enable a more sustainable mode of operation at the existing dump site in Mawlamyine it is proposed to:

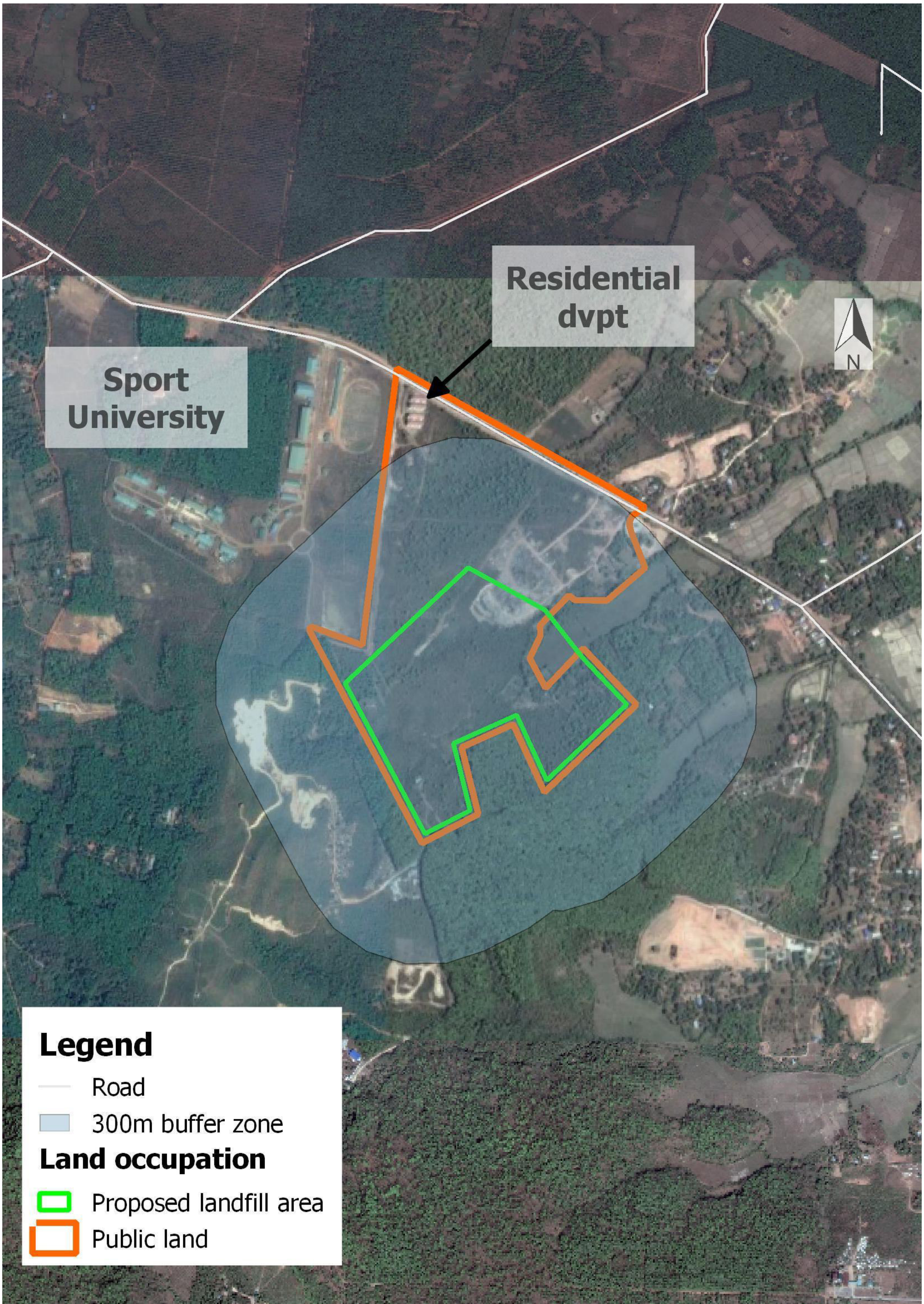
- move the existing solid waste into one confined area. This waste will be removed to landfill cell I as soon as the first landfill cell has been completed;
- To build a first landfill cell with 5 year life span capacity, separated in 5 sub-cells to facilitate the hydraulic flow of leachates;
- introduce a managed landfill concept;
- to prepare a part of the site for Composting Plant area;
- to purchase small pieces of land to make a more sizable landfill site location (more rectangle size, is easier and much more economical for construction than a "spaghetti-size" area.)

The location of the existing dump site and proposed landfill area is shown on Figure 3-43.

Design of the proposed landfill will include clay lining, groundwater monitoring, planned cell development, leachate collection and storage, surface water management, and regular covering of waste and controlled waste picking. A separate area for medical waste will be provided with a small incinerator with shed for infectious waste.

The sanitary landfill will be fenced to control the access.

Figure 3-43: Mawlamyine Proposed Landfill and Existing Dump Site



There are three critical elements in a controlled landfill:

i) a bottom liner,

ii) a leachate collection system,

iii) a final cover.

Landfill bottom liners are made of high density polyethylene (HDPE) to avoid any leakage of leachate into the soil. An HDPE liner is minimal 1.5 mm thick and is normally installed by a specialist supplier to 'welt' the sheets together. Normally an HDPE liner is delivered on rolls of 7.00m width with a length of 140m. The liner shall be a composite barrier having 1.5 mm HDPE or equivalent having permeability less than $1*10^{-7}$ cm/sec. The water table should be at least 2 m below the base clay or amended soil barrier layer.

The liner system should also be applied on side slopes. To install the HDPE liner, it should be kept out of sunlight otherwise it will be damaged through the action of ultraviolet radiation (Figure 3-44).

Figure 3-44: Liner system of Controlled Landfill

Leachate is water which is contaminated by contacting the wastes. It seeps to the bottom of a landfill and is collected by a system of pipes (Figure 3-45). The pipes laid along the bottom capture the contaminated water (leachate). The pumped leachate is treated at a leachate treatment unit, see further for details of leachate treatment.

Figure 3-45: Leachate collection system of controlled Landfill

To reduce the leachate volume, the disposed waste should be covered daily with soil to avoid rainfall intruding the landfilled waste.

Leachate control

Even with good operational practices and surface water controls, most landfills will generate leachate. This leachate must be managed so as to prevent contamination of groundwater and surface water. Leachate management is best accomplished through the installation of a landfill liner and the installation and operation of an engineered leachate collection/conveyance system.

Leachate Treatment options in this project include the following:

- Recirculation back into the landfill;
- Passive evaporation to the atmosphere (often through holding ponds or storage lagoons)
- On-site physical and biological treatment.

The sequence as mentioned above will be utilized for the treatment of leachate, this depending on the rainfall/day. The first option is practicable with low to normal rainfall, after which the second option will be applied.

The on-site physical biological treatment is the last option and may be used during heavy monsoon rains when storage is not sufficient. At this stage in the project, a simple treatment unit with physical treatment (sedimentation, settling pond) and biological treatment (e.g. through surface aerators) is foreseen.

At the closure of the landfill cells after 5 years of operation, a final cover or cap over the landfill cell will keep precipitation water out (to prevent leachate formation) of the landfill. It generally consist of several sloped layers: clay or membrane liner (to prevent rain from intruding), overlain by a permeable layer of sandy or gravelly soil (to promote rain runoff), overlain by topsoil in which vegetation can root (to stabilize the underlying layers of the cover).

Environmental monitoring: Ground Water Monitoring Wells: Total to be installed numbers = 6 (1 well up-gradient of the ground water flow; 5 wells along the sides in down-gradient direction); all wells 30m away from landfill.

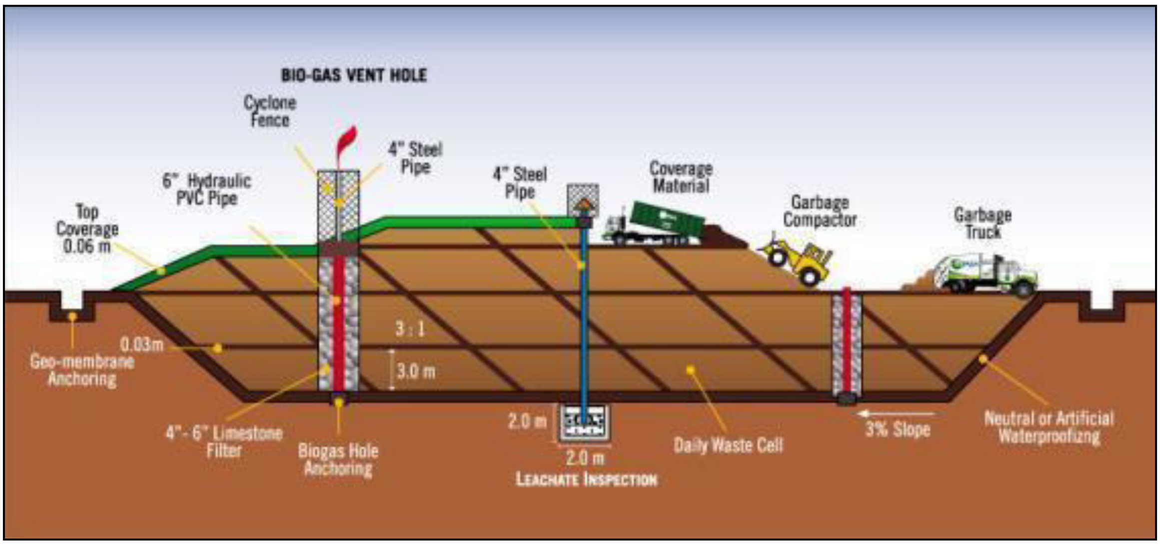
The main principles for a controlled Landfill are presented in Figure 3-46.

Note on Landfill Gas

Aerobic decomposition begins immediately after organic waste disposal in the landfill and continues until all of the entrained oxygen is low or not present anymore. This process generates landfill gas (LFG) which is harmful to the environment. The potential impacts is most significant at landfills of significant size (nominally >1Mt waste capacity). In case of mixed waste landfills, they should have LFG collection and control systems installed that are designed and operated to minimize both LFG migration and emissions. The landfill gas is either burned off in a flare, or used to generate electricity in a gas turbine.

It is however limited in this project by diverting the biodegradable waste to the compost plant and disposing in the landfill mainly inert waste with low quantities of biodegradable waste rejects. Additionally the landfill is relative small and LFG control can be achieved by passive venting, no flaring is required. However, it is important to monitor on a regular bases (e.g. once/month) if landfill gas is produced. Experiences with similar landfill systems show that no significant landfill gas is produced at inert waste landfills.

Figure 3-46: Principles for Construction of Controlled Landfill



EQUIPMENT REQUIRED FOR LANDFILLING

For daily spreading and soil covering a bulldozer is required. The bulldozer also compacts the waste, although not as the same level as a specialized Compactor Machine. In this project with a relative small landfill size, a Compactor is not required and a bulldozer has more diverse operational options compared to a compactor.

A small tractor with cart-trailer will be used for carrying on-site the daily cover material and for transport of separated waste from the compost plant and other works on-site. It is assumed that the front-end loader from the compost plant can be used for the small quantities to be loaded. A second front-end loader only for the landfill is not required during the first phases of the landfill operation. At the long term it is maybe necessary to operate an additional front-end loader. A second loader is not included in the Investment costs.

3.3.11 PRELIMINARY DESIGN

The preliminary design consists of the following sections:

- Collection Strategy
- Recycling improvement
- Composting
- Controlled Landfill

COLLECTION STRATEGY

Primary Collection trucks for a critical distance below 10 km

In parallel with the density of population, the waste generation per wards is denser in the historical area of the city. This is particularly accentuated by the presence of the main markets. The following Figure 3-47 displays a big densification of the waste generation in downtown area while wide wards in the South would remain low densified.

Five collection zones are proposed to analyse the type of truck adapted to each area.

Figure 3-47 Waste generation per ward in t/d/km² in 2015 and 2040

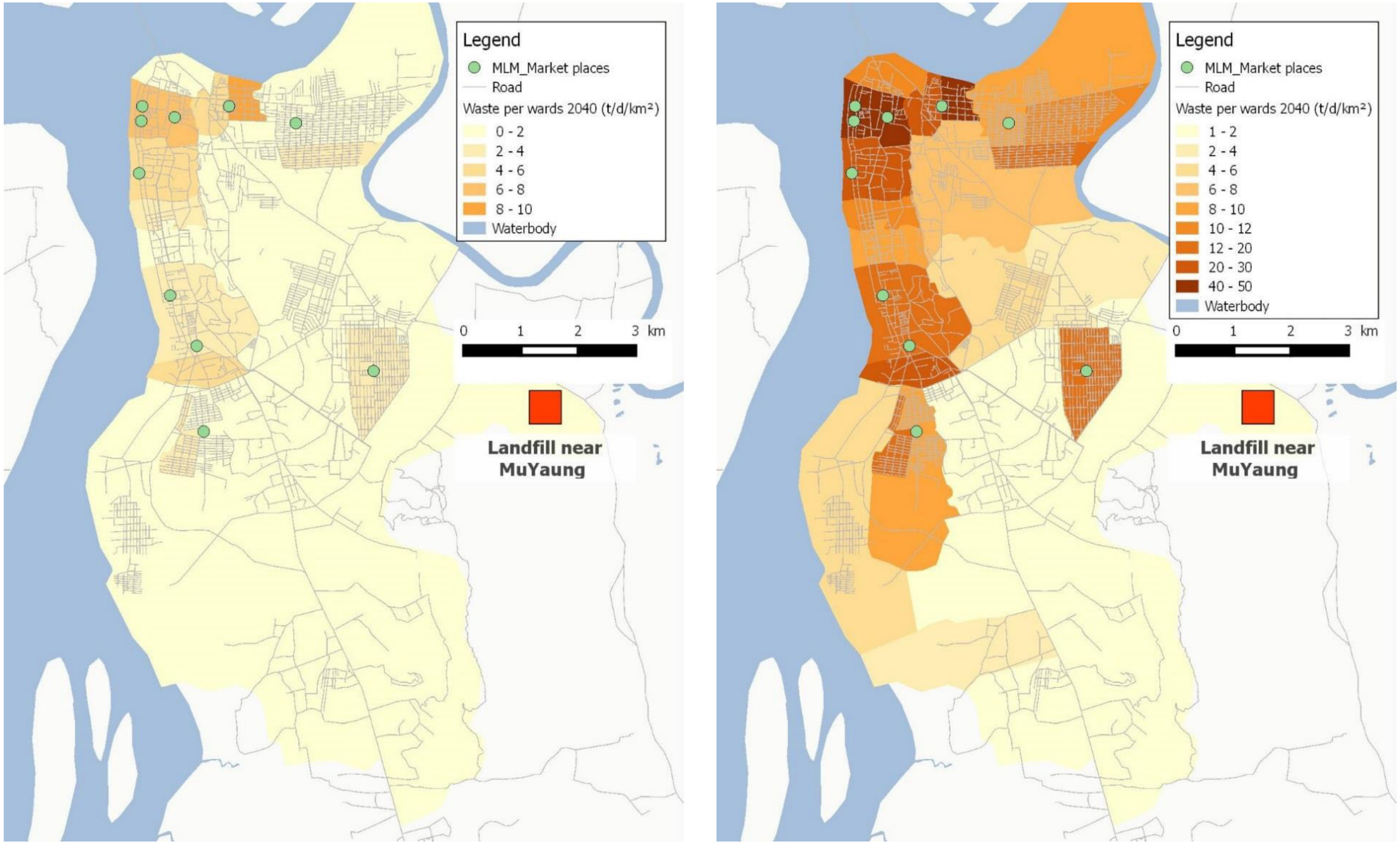
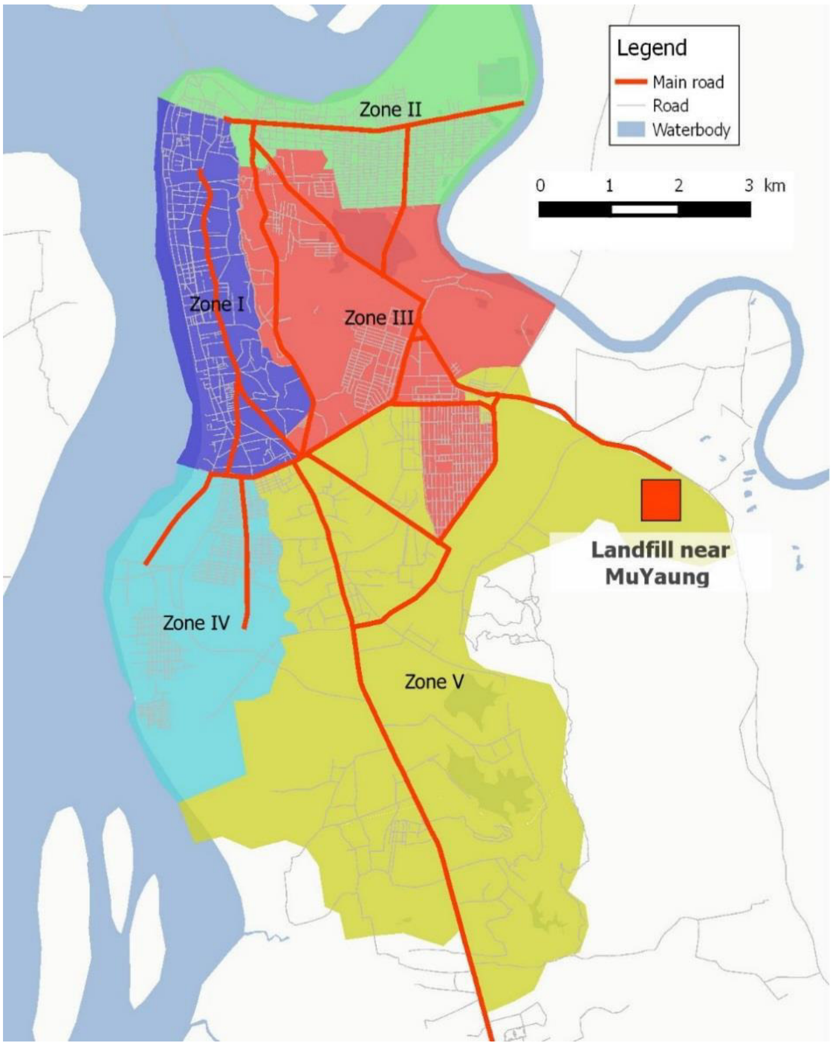


Figure 3-48 Proposed solid waste collection zones for Mawlamyine



Four type of trucks have been studied for Mawlamyine SWM with the following assumptions:

Type	Tractor	Dumper Small	Dumper Large	Compactor
Capacity (m3)	4-5	7-8	10	13-16
Compaction ratio	1	1	1	2
Average speed	12	12	12	12

Table 3-26 Number of small tractors needed to fulfill collection requirements

Tractor (cap: 4 m3)	distance to landfill (km)	trip duration (2 ways) (in h)	Maximum trips / day (working 7 h/d)	Maximum Cap/truck/d	Waste collected 2015 (t/d)	Waste collected 2040 (t/d)	Trucks needed 2015	Trucks needed 2040
Zone I	10.5	1.8	4	16	19.2	108.4	1.2	6.8
Zone II	8	1.3	5	20	26.5	149.7	1.3	7.5
Zone III	6	1.0	7	28	14.5	81.9	0.5	2.9
Zone IV	9	1.5	5	20	11.3	63.6	0.6	3.2
Zone V	9.5	1.6	4	16	8.5	48.2	0.5	3.0
						Trucks needed	**5**	**24**

Table 3-27 Number of small dumpers needed to fulfill collection requirements

Dumper small (cap: 7 m3)	distance to landfill (km)	trip duration (2 ways) (in h)	Maximum trips / day (working 7 h/d)	Maximum Cap/truck/d	Waste collected 2015 (t/d)	Waste collected 2040 (t/d)	Trucks needed 2015	Trucks needed 2040
Zone I	10.5	1.8	4	28	19.2	108.4	0.7	3.9
Zone II	8	1.3	5	35	26.5	149.7	0.8	4.3
Zone III	6	1.0	7	49	14.5	81.9	0.3	1.7
Zone IV	9	1.5	5	35	11.3	63.6	0.3	1.8
Zone V	9.5	1.6	4	28	8.5	48.2	0.3	1.7
						Trucks needed	**3**	**14**

Table 3-28 Number of large dumpers needed to fulfill collection requirements

Dumper large (cap: 10 m3)	distance to landfill (km)	trip duration (2 ways) (in h)	Maximum trips / day (working 7 h/d)	Maximum Cap/truck/d	Waste collected 2015 (t/d)	Waste collected 2040 (t/d)	Trucks needed 2015	Trucks needed 2040
Zone I	10.5	1.8	4	40	19.2	108.4	0.5	2.7
Zone II	8	1.3	5	50	26.5	149.7	0.5	3.0
Zone III	6	1.0	7	70	14.5	81.9	0.2	1.2
Zone IV	9	1.5	5	50	11.3	63.6	0.2	1.3
Zone V	9.5	1.6	4	40	8.5	48.2	0.2	1.2
						Trucks needed	**2**	**10**

Table 3-29 Number of compaction trucks needed to fulfill collection requirements

Compactor (cap: 16 m3)	distance to landfill (km)	trip duration (2 ways) (in h)	Maximum trips / day (working 7 h/d)	Maximum Cap/truck/d	Waste collected 2015 (t/d)	Waste collected 2040 (t/d)	Trucks needed 2015	Trucks needed 2040
Zone I	10.5	1.8	4	104	19.2	108.4	0.2	1.0
Zone II	8	1.3	5	130	26.5	149.7	0.2	1.2
Zone III	6	1.0	7	182	14.5	81.9	0.1	0.5
Zone IV	9	1.5	5	130	11.3	63.6	0.1	0.5
Zone V	9.5	1.6	4	104	8.5	48.2	0.1	0.5
						Trucks needed	**1**	**4**