Chapter 8

Selection of an Optimum Technical System

8 Selection of an Optimum Technical System

8.1 Policy for Selection of an Optimum Technical System

8.1.1 Criteria for Selection

Taking the current situation and background of SWM in DSM considerably into account, the policies for the selection of a technical system are as follows:

1) Systems and technologies to be adopted should be as simple as possible so that operation and maintenance would be easy and inexpensive.

2) The foreign currency requirements for the purchase, operation and maintenance of systems should be minimised. The use of locally available materials and services should be maximised.

3) The use of labour intensive rather than capital intensive techniques should be used where technically feasible and economically viable.

4) Technical system proposals have to be consistent with the institutional requirements which have been outlined in Chapter 5 to ensure their efficiency.

8.1.2 Selection Procedure of an Optimum Technical System

An SWM technical system consists of various technical subsystems such as discharge and storage system, collection and transportation system, street sweeping system, intermediate treatment system, final disposal system, etc. A number of alternatives can be formed from the combination of these various subsystems. Hence, selection of the optimum technical system will be carried out according to the following procedures.

1. Examining preconditions for selection of subsystems
2. Identification of potential subsystem technologies for DSM
3. Screening potential subsystem technologies
4. Comparison of estimated unit refuse collection and transportation costs by the type of vehicles
5. Selection of an optimum technical system

8.2 Preconditions for Selection of Subsystems

The important factors, such as preconditions, requirements, etc., to be kept in mind regarding the selection of an optimum technical system are summarised below.

a. Location and Number of Final Disposal Sites

The formulation of the optimum technical system was mainly influenced by the location and number of proposed disposal sites, which was determined based on the following policies established by DCC for the study in August 1996:

- The proposed SWM Master Plan complies with the basic concept for the allocation of the future disposal site of DSM city, which is the construction of a disposal site in the districts of Kinondoni, Ilala and Temeke.
- The Kunduchi New MECCO quarry site shall be used as the new disposal site for the Kinondoni District.
- The new disposal site for the Temeke district will be constructed either in the Charambe, Toangoma or Kipawa wards.
- The new disposal site for the Ilala district will be constructed in the Pugu ward.

Consequently, the average waste transportation distance in 2005, between the districts and their respective future disposal sites, will be about 18 km.

b. Collection and Transportation System for Private Operators

Private operators in principle independently choose the collection and transportation system they think is most suitable. Further, they usually have limited capacity and resources. Therefore, the collection and transportation systems of private operators are ordinary excluded from the SWM master plan. However, the collection and transportation systems adopted by these contractors is be covered, in view of the possibility that they might require governmental support for the expansion of their services.

8.3 Identification of Potential Subsystems for DSM

The screened potential subsystems for DSM are listed in Table 8-1.

Table 8-1: Potential Subsystems for SWM in DSM

Technical Systems	Technical Sub-systems	Sub-system Components
Discharge and Storage	• Source Separation	• Mixed discharge • Separate discharge
	• Type of Storage Equipment	• Paper or plastic sacks • Dustbins • On-site storage • Containers (1 to 2 m^3) • Skips
Primary Collection	• Type of Collection System	• Handcart • Animal cart • Human pedal cart • Cart attached to motorbike • Three-wheel autorikshaw
Secondary Collection and Transportation	• Collection Frequency	
	• Collection Method	• Mixed collection • Separate collection
	• Type of Collection Service	• Curb collection • Door-to-door collection • Bell collection • Point collection • Public container collection
	• Collection Schedule	• Day collection • Night collection
	• Type of Collection Vehicle	• Compactor truck • Tractor and trailer • Tipper truck • Skip truck • Handcart
	• Transportation System	• Motor vehicle • Railway • Water Haulage
	• Transfer Station	
Street Sweeping	• Cleaning Method	• Manual street sweeping • Mechanical cleaning • Vacuum cleaning • Flushing
Intermediate treatment	• Incineration • Refuse Drive Fuel (RDF) • Biogas Production • Pyrolysis	
	• Composting	• Centralised composting plant • On-site/community based composting
	• Size Reduction • Mechanical and Scavenging Sorting	
Recycling	• Government Related • Private Sector Centred	
Final Disposal	• Method of Sanitary Landfill	
Maintenance of Vehicles and Equipment	• Preventive Service Workshop • Full Service Workshop	

8.4 Screening Potential Technologies

8.4.1 Discharge and Storage System

Refuse is generated on a somewhat continuous basis. However, collection occurs intermittently, a few times a week or perhaps daily, depending on the quantity generated at a specific site and climatic conditions. Therefore, it is necessary to provide proper on-site storage for refuse until it is collected.

Storage is quite important because it can have a significant effect on:

- public health and aesthetic conditions
- subsequent functional elements such as collection
- public attitudes concerning the operation of the system

The effects on the above aspects vary depending on the generation source, i.e., residence, shops, offices, buildings, etc.

Accordingly, this section deals with available on-site handling and storage systems for DSM.

a. Effects on On-site Handling and Storage

a.1 Public Health and Aesthetic Conditions

In DSM, handling and storage of household waste is most important because household waste percentage exceeds the total by 75 %. Further, most of the wastes are generated in densely ppopulated areas where storage space is limited, thereby having significant impacts on public health and aesthetic conditions.

Public health concerns are related primarily to the infestation of storage areas for solid wastes with vermin and insects that often serve as potential vectors of disease. By far the most effective control measure for both rats and flies is proper sanitation. Typically, this involves the use of paper, plastic bags, or containers with tight lids, the periodic washing of the containers as well as of the storage areas, and the periodic removal of biodegradable materials, which is especially important in areas with a warm climate such as DSM.

Aesthetic considerations are related to the production of odours and the unsightly conditions that can develop when adequate attention is not given to the maintenance of sanitary conditions. Most odours can be controlled through the use of containers with tight lids and with the maintenance of a reasonable collection frequency, or through the timely discharge of refuse by dischargers with punctual refuse collection services. To maintain aesthetic conditions, the container should be scrubbed and washed periodically.

a.2 Subsequent Functional Element

Storage and collection are separate operations but must be closely coordinated. The type, size and location of containers are very important factors in determining the most efficient collection system. Large size public containers are favourable in terms of public health and aesthetic conditions but difficult to load manually. Small containers are quite convenient for loading wastes but reduce waste collection efficiency because they require more frequent stops for loading.

a.3 Public Attitudes in the Operation of the System

It is necessary to pay sufficient attention to the security of equipment including waste containers, to be installed in DSM. There is always a risk that dustbins and containers could get stolen because they are handy and can be used for other purposes.

b. Present Storage Systems

The town regulation obliges dischargers to use appropriate containers when discharging wastes. However, the use of dustbins or some type of bag are hardly seen in DSM, where the majority discharge wastes without any storage system, thereby causing sanitary and aesthetic problems, as heaps of refuse scatter ubiquitously. In addition, this condition also makes the loading of waste onto refuse collection trucks very difficult.

c. Potential Storage Systems

The applicability of the use of the following four storage systems, which are commonly used in many countries, in DSM are discussed below.

- Paper or plastic sacks
- Dustbins
- On-site refuse storage
- Containers (1 to 2 m^3)
- Skips

There are a wide range of issues to be considered in the selection of the most appropriate storage system for DSM. The examples are as follows.

- The amount and composition of waste discharged.
- Waste composition and components.
- The collection frequency, most often determined by climate and waste composition.
- The space available near the source and the accessibility of the area to collection vehicles.
- Environmental and occupational health hazards.
- Suitability to the actual environment, i.e., functions suitable for the actual user.
- The ability to stand misuse, rough climate, and animals scavenging.
- The total investment and operational costs over a given period.
- The habits and traditions of users and collection crews.

8.4.1.1 Paper or Plastic Sacks

The paper or plastic sack system generally entails the use of 20 to 80 litres sacks for the storage and handling of wastes which are later collected for further transportation and disposal. They are therefore expendable. This system can be used by any discharger, i.e., residents, shop owners.

Advantages

- The system is very sanitary because the sacks are disposable.
- The system is labour and time saving because the sacks are light in weight and expendable thereby requiring less time and effort for haulage.
- The system does not require any initial investment.

Disadvantages

- The system requires the continuous purchase of sacks.
- The use of expendable sacks increases the waste generation amount.
- Sacks can easily be torn by cats, dogs or children or when too full.
- The contents of sacks when left untied may scatter widely at pick-up points.

Applicability

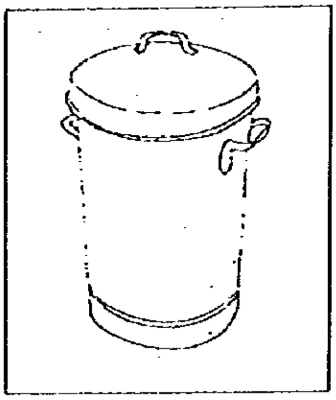
Although sacks require less capital, the expenditure for its continuous purchase usually exceeds that for the provision and maintenance of permanent containers. However, although the DSM citizens might find it difficult to cope with the associated financial burden, the use of sacks is still more affordable than permanent containers. In addition, the price of local plastic sacks, 25-75 Tsh, is foreseen to depreciate with the increase in demand.

The use of sacks will only slightly increase the waste generation amount.

Not many stray cats and dogs, which often cause the tearing of sacks, are seen in DSM. Accordingly, it is presumed that refuse scattering will result from the scavenging of people in the streets rather than animals.

As a conclusion, the only point that is critical to the selection of this system is cost. There may be difficulties in enforcing the use of this system at the expense of householders, unless the DCC or private collectors continue to provide the sacks. This system may be recommended, provided problems on sack provision and the exorbitance of house-to-house or curbside collection are solved.

8.4.1.2 Dustbins



Dustbins herein refer to all small-size containers with lids, ranging from 30 litres to about 120 litres in size. One man can reasonably lift and empty containers weighing up to about 28 kg (70 litres), while two men are required to lift a 48 kg (120 litres) container. Dustbins of the former size may be used at individual premises or as communal dustbins for 6 to 12 families either on or farther from the collection points. They can also be used as litter bins for street sweepers or the general public.

The dustbins may be made of galvanised steel or high density polyethylene and must be weather resistant.

Litter bins can be a simple half cut empty drum. They should be inexpensive because they get stolen easily. Unless it adversely affects collection efficiency, each litter bin should be properly affixed with locks.

Advantages

- This system provides sanitary conditions because wastes stored can be completely covered.
- This system maintains aesthetic conditions.
- This system lasts for more than several years.

Disadvantages

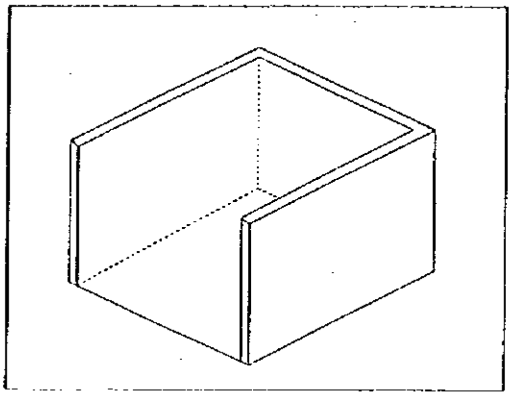
- This system requires a large initial investment for the purchase of dustbins.
- Dustbins require periodical washing to maintain their sanitary condition.
- Dustbins are easily stolen because of their usefulness.

Applicability

In contrast with the use of sacks, this system is less expensive in the long run. However, the capital it requires is too big for the dischargers and the responsible bodies in DSM to cope with. The introduction of this system is financially infeasible, unless a donor(s) is found.

Dustbins are very convenient, therefore they are usually stolen. Further, their introduction would be much more expensive than the present collection system because it would mean the implementation of a curbside or house-to-house collection system. Therefore, the dustbin system is not suitable for DSM.

8.4.1.3 On-site Refuse Storage



The on-site refuse storage is commonly made of bricks and mainly used to store communal refuse. With this storage system, it is possible to keep different types of wastes separately in different compartments. The usual capacity of this type of storage ranges from 1 - 2 m^3.

Advantages

- This system maintains aesthetic conditions.
- This system is durable enough to last more than 20 years.
- This system is favourable to separate collection.
- *Disadvantages*
- This system requires a huge capital.
- This system requires close monitoring for the maintenance of sanitary conditions.
- This system requires space.
- It is very difficult to select a location for on-site refuse storage because it is a permanent fixture and it might cause public nuisance.
- This system makes loading of waste onto refuse collection trucks very difficult.

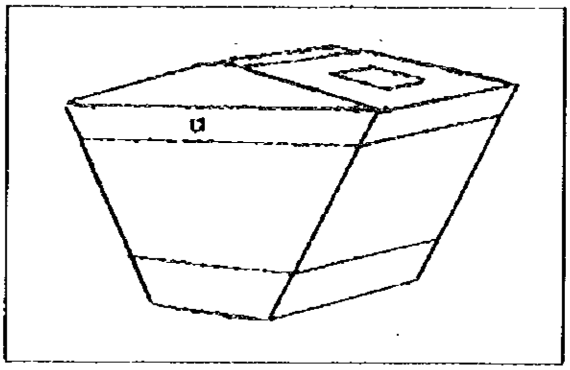
Applicability

This system requires close maintenance services, therefore, it is only applicable in markets and high income residential areas where people can afford the cost it incurs.

This system is not suitable for middle and low income residential areas and unplanned developed areas in DSM because lack of space, difficulties in deciding its location, and in maintenance.

This system requires a big investment but increased efficiency in collection works does not lead to cost-effectiveness. Therefore, this system is not recommended unless users are willing to bear the extra costs.

8.4.1.4 Containers (1 to 2 m^3)



The container (1 to 2 m^3) system is commonly used for small apartment buildings, multi-purpose buildings, offices and commercial buildings.

Containers of any size may be used for the temporary storage of waste, but there are two main constraints. One is weight limitation for consistent manual haulage and transport to avoid undue fatigue and bodily injuries. Containers may be fitted with wheels and moved by a small hand truck from the storage stands to the collection vehicle or to an intermediate storage point. However, the use of containers exceeding the weight limitation for manual haulage and transport require that the surfaces over which these containers are to be placed and wheeled must be reasonably even, hard and without steps or steep inclines.

It is very important to wash the containers and clean its surroundings. The frequency of cleansing would depend largely upon the kind of waste stored in the containers. The cleansing of containers is difficult, exhausting, and costly. Cleansing is usually more satisfactory if it is undertaken in the central maintenance depot where steam sweeping equipment or high pressure jets can be installed.

Advantages

- This system provides sanitary conditions.
- This system maintains aesthetic conditions.
- This system is durable enough to last several years.

Disadvantages

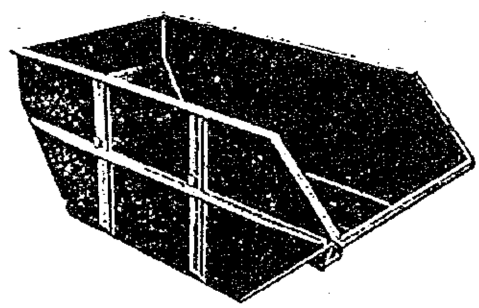
- This system requires a huge capital.
- This system requires even concrete floorings and equipment for lifting containers.
- This system requires periodical washing to maintain sanitary conditions.
- The operation of this system is considerably expensive.

Applicability

The required capital is too big as this system requires containers, lifting equipment, and even concrete floorings. Cost saving cannot also be expected from increased efficiency in waste collection activities. Conclusively, the introduction of this system is hardly cost effective.

8.4.1.5 Skips

Containers measuring 5 - 20 m³ or bigger are suitable for areas generating large quantities of waste. Special purpose vehicles are required for lifting, transporting and emptying such containers. A constraint to the use of such containers would be the need for room at the storage location for the vehicle to manoeuvre, to complete the container collection or exchange process.



Advantages

- This system provides sanitary conditions.

- This system maintains aesthetic conditions.
- This system is durable enough to last more than several years.
- This system can curtail collection and transportation costs because it minimises loading time.

Disadvantages

- This system requires a huge capital.
- This system requires special vehicles for lifting, transporting and emptying containers.
- This system requires space for placing and lifting containers.
- Irregular collection can cause hazards as the huge amount of waste stored in these containers are left for a considerable period of time.

Applicability

The required capital is too big as this system not only requires containers but special vehicles as well. This system would be financially too difficult to introduce without a donor. However, because of the financial benefit that can be gained from this system, i.e. reduced collection and transportation costs -- usually much greater than the cost for containers and special vehicles -- its introduction shall be taken into consideration together with the collection and transportation system.

8.4.1.6 Conclusion

The absence of a proper waste storage system in DSM is one of the main causes of the aesthetic and public health problems, as well as deteriorating public morale. To rectify these conditions, proper handling and storage systems should be introduced.

Dustbins and container (1 to 2 m^3) systems are not recommendable because not only do they require huge initial investment but also hardly contribute to the reduction of collection and transportation costs.

On-site refuse storage system is generally not recommended for residential and commercial areas, unless users are willing to shoulder the required extra costs. However, this system can be recommended for market use as long as it is equipped with an elevation to facilitate loading works.

The large container system requires a huge investment but contributes to the reduction of large collection and transportation operation costs. However, this system is only recommendable if the initial investment problem can be solved. The sizes of the containers shall be determined according to their purposes and distribution. These containers are usually placed at collection points for markets and unplanned areas inaccessible to refuse collection vehicles.

The paper and plastic sacks system is the easiest system to introduce because it requires no investment. The difficulty part however lies in making dischargers provide their own sacks. The re-use of plastic bags distributed in stores or grocery shops for waste discharge is a sound alternative to this problem. Although not all department stores or grocery shops in DSM distribute such bags, this is foreseen to increase in the future.

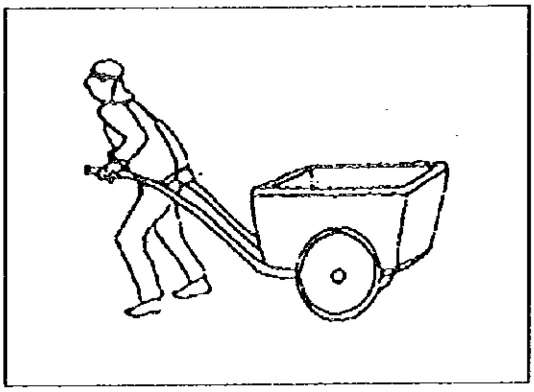
The use of a skip or plastic sacks highly depends on the collection and transportation system to be adopted. Therefore, the optimum storage system shall be selected from these two systems in line with the proposed collection system.

8.4.2 Primary Collection

In areas with inaccessible roads, waste has to be carried to designated points for collection. People living near collection points find it easy to discharge waste by themselves, but those further away have difficulties doing so. Therefore, a primary collection service, which is the haulage of waste from residences to collection points, should be established for the latter. People living near collection points may also subscribe to door-to-door collection services as long as they are willing to pay for the services.

This section discusses the suitability of several potential systems to the area.

8.4.2.1 Handcarts



Handcarts are commonly used in developing countries for various purposes. In DSM, they are widely used to sell water, a fact that proves its suitability as a waste collection tool for the city of DSM.

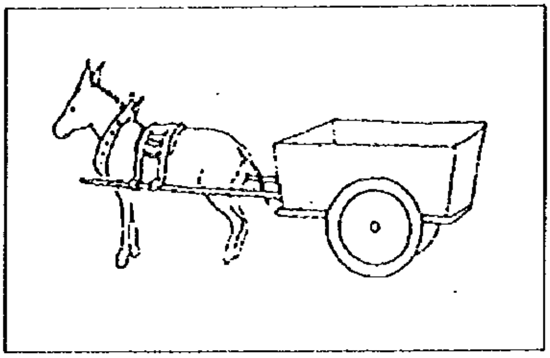
Handcarts are used in developing countries for daily house-to-house collection, in particular, collection along very narrow streets that are inaccessible to motor vehicles. Typically, handcarts are made of open boxes that are attached to a frame, and the only way of emptying the cart is to discharge the load on the ground. Reloading is then carried out with a shovel or a basket. The typical radius of operation of a handcart is about 1 km[1].

Improvements in the design of handcarts over the years have been primarily concentrated on ensuring that unloading of waste collected does not entail contact with the ground. The use of a number of covered containers, usually between four and six, which can be lifted off the cart for unloading, has enabled the cart to carry payloads of about 150 kg which can be speedily and hygienically transferred to secondary collection containers or vehicles.

Because handcarts have been very common for a long time in DSM, its suitability has been proven. Therefore, this system is recommended for DSM, especially in view of the improvements in the carriage of waste .

[1] "Solid Waste Management for Economically Developing Countries", L. F. Diaz et. al., ISWA and CalRecovery, 1996

8.4.2.2 Animal Drawn Carts



Horses were widely used in North America and in Europe for door-to-door refuse collection up until World War II. In Japan, cows were used for waste collection until the 1960s. Horses, mules, donkeys and cows are still used in several countries around the world. The capacity of animal carts generally ranges between 2 and 4 m^3. In some cases, the carts are equipped with bodies that can be tipped, by either pivoting the body or by using a manually-operated worm and nut mechanism. The effective radius of operation is about 3 km[2]. Animal carts have the following advantages and disadvantages:

Advantages

- no consumption of fossil fuels.
- quiet operation.

Disadvantages

- It is less manoeuvrable than human handcarts.
- The required capital cost is higher than human handcarts.
- Animal carts may interfere with traffic.

Applicability

This system is considered to be technically suitable for DSM. However, there can be other problems. Publications concerning solid waste management in developing countries often explain that one of the advantages of the use of animal drawn carts is low capital investment. However, this is not applicable for DSM where the use of handcarts would be more economical. Because animal drawn carts require human help they incur more expenses and are, therefore, not common in DSM where even handcarts are very expensive. It is, therefore, necessary to acquire financial support to be able to promote this system in DSM. On the other hand, there is also a possibility that the animals, especially cows, used to pull these carts will be sold because of their profitability.

8.4.2.3 Pedal Cart

Pedal carts are commonly used in Latin America and in Asia. They have an effective radius of operation of about 2 to 3 km[3].

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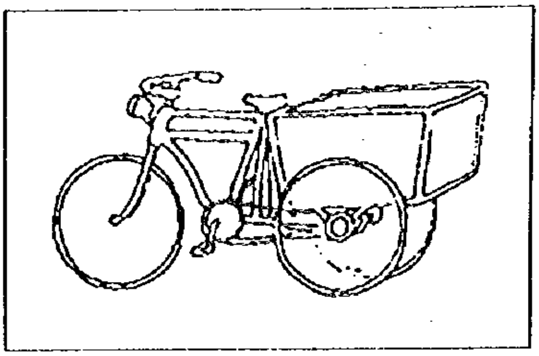
[2] "Solid Waste Management for Economically Developing Countries", L. F. Diaz et. al., ISWA and CalRecovery, 1996

[3] "Refuse Collection Vehicle for Developing Countries", UNCHS

Advantages



- It has a longer working radius than handcarts because it has more speed
- Environmentally sound system

Disadvantages

- Its volumetric capacity is less than the handcart
- It requires more capital than handcarts

Applicability

This system is technically suitable for DSM. However, it will not be widely used because it is costly. Financial support should be acquired therefore for the introduction of this system. There is also a possibility that these bicycles will be used for other means instead.

8.4.2.4 Motorised Cart

A motorised cart is a motorbike equipped with a box in front or at the rear. This system is used in DSM by TTCL for transport of materials.

Advantages

- It has a longer working radius than handcarts and pedal carts, because it has more speed.
- Its volumetric capacity exceeds that of a pedal cart.

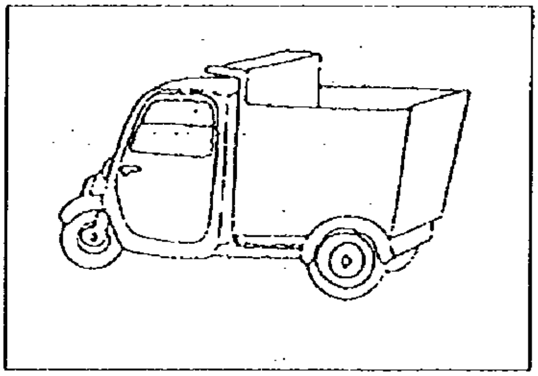
Disadvantages

- Its volumetric capacity is less than the handcart.
- It requires more capital than the handcarts and pedal carts.

Applicability

The capital and O & M costs of this system is too expensive for primary collection in DSM. Therefore this system is not suitable for DSM.

8.4.2.5 Motorised Tricycles



The two-stroke, three-wheel motorcycle is a very common means of transportation in several developing countries and a viable alternative for waste collection. The tricycle can be fitted with a high level topping body of about 2 m^3 capacity while retaining a low loading line. The tricycle is commonly used in several cities in Asia, particularly in the old sections of the cities where streets are too narrow to allow passage of larger vehicles. Its relatively high speed gives this system an operating radius of about 10 km[4] .However, tricycles do not operate well on rough, unpaved roads such as those in marginal areas or those which typically lead to disposal sites.

This system is not recommended for DSM because the required capital and O & M costs are too expensive for the primary collection system and because the road conditions in DSM are not favourable to this system.

8.4.2.6 Conclusion of Primary Collection System

The primary collection system to be selected must require as little capital as possible because the payment, based on the number of collection trips, for wastes collected through this system is expensive in itself. The system shall also be very manoeuvrable because the roads in areas where primary collection is needed are unpaved and very narrow.

Conclusively, the handcart is considered as most suitable for DSM.

8.4.3 Collection and Transportation System

The objective of waste collection and transportation system is to collect and to transport waste from specific locations to a disposal site at regular intervals, with minimal cost and in a reliable manner, with due considerations of sanitary conditions. It is very important to always bear in mind that the cost for the collection and transportation of waste is by far the most expensive part of the overall waste management system.

The collection and transportation system is mainly affected by the following aspects:

- collection frequency
- collection method (mixed or separate)
- collection system
- collection schedule
- collection vehicle
- transportation distance
- transportation method
- transfer system

[4] "Solid Waste Management for Economically Developing Countries", L. F. Diaz et. al., ISWA and CalRecovery, 1996

a. Collection Frequency

Collection frequency is determined in view of sanitary conditions, operation and maintenance cost. As for organic waste, the more frequent collection is carried out the better in terms of sanitation. However, because this would mean higher costs, collection frequency should be minimised as long as sanitation is maintained.

Considering its tropical climate, i.e., high temperature and humidity, waste composition including high percentage of organic fractions, and high population density, etc., a twice or thrice weekly collection is recommended for DSM.

b. Mixed or Separate Collection

A separate collection system is required by introducing intermediate treatment technologies. Introduction of incineration technology requires separate collection of combustibles and noncombustibles. Composting requires separate collection of organic and inorganic materials, while recycling requires separate collection of recyclable and unrecyclable materials.

The separate collection system requires additional costs because it necessitates more storage space, and reduces waste collection and transportation efficiency.

Another issue to be kept in mind is people's willingness to cooperate in source segregation. Because this necessitates the conduct of public education and motivation programmes, it would take time before it is adequately implemented.

In principle, mixed collection should be implemented in DSM provided that no intermediate treatment technologies are employed.

However, the study acknowledges the importance of conducting a separate discharge system, even without a separate collection system, at an early stage to succeed in the introduction of a separate collection system in the future.

c. Collection System

To consider the appropriateness of the collection system, the collection efficiency, the town structure, and the present use of the area are the main factors to consider.

Table 8-2: Summary of Collection Systems

Collection System		Summary
Point Collection		Dischargers carry their own waste to specified waste collection points; discharged wastes are later collected by refuse trucks.
Curb Side Collection		Each household is responsible for placing the containers at the curb on collection day and for returning them to their storage location.
Door to Door Collection	Set-out - Set-back	Containers are set out from the premises and set back after being emptied by additional crews that work in conjunction with the operators responsible for loading the collection vehicle.
	Setout	Set out collection is essentially the same as set-out-set-back collection, except that residents are responsible for returning the containers to their storage location.
	Backyard Collection	The collection crew enters the premises and collects wastes from their storage location.
Bell Collection		The collector calls out to the residents to discharge their waste upon the arrival of collection vehicle at a given collection point.
Public Container Collection		Residents discharge waste regardless of collection day. This collection method produces a high collection efficiency.

In DSM, point collection, curb collection, bell collection systems and door to door systems are used. The bell collection system has been introduced in residential areas since early 1996 by private collectors and is observed to be effective. The point collection system together with the bell collection system is widely used in residential areas. Door to door and curb collection systems are used in some commercial areas in the city centre.

The following collection systems are recommended for further examination:

- point collection system for residential areas
- door to door collection system for commercial, institutional and high income residential areas

d. Collection Schedule

Setting a proper collection time is important to achieve an effective collection system. The factors to be considered are traffic, current town structure, electrification, etc.

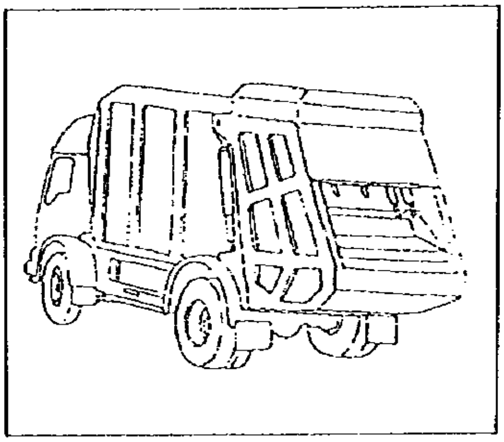
Night collection is inappropriate in most areas in DSM except the city centre where few street lights are provided.

In the city centre, traffic is very congested and many vehicles park along the roadside between 8 a.m. and 5 p.m. Waste collection is not efficient during this period. Night collection is more efficient in areas where lighting is sufficient, although the noise this will generate is forecast to aggravate nearby residents. Therefore, collection work should be carried out in the early morning before 8 a.m., or before 9 p.m. for the city centre.

e. Collection and Transportation

e.1 Haulage

e.1.1 Compactor Trucks



The use of rear end loading compaction vehicles have become the norm in many industrialised countries, where they are designed specifically for the following purposes:

- Maximisation of productivity of highly paid labour force.
- Compaction of low density wastes to achieve higher payloads.

In industrialised countries, these compaction vehicles are used to haul a waste density of 100 to 200 kg/m^3 from the collection points. In DSM, the average waste collection density is 390 kg/m^3.

A compaction ratio of 2 or 3% is necessary to justify the adoption of such a vehicle for DSM. Only a maximum compaction ratio of 1.5% can be expected from DSM's waste.

Conclusively, these vehicles are inappropriate in most areas in DSM, as confirmed by the ineffective operation of the 6 screw compaction trucks (Iveco, Italy) introduced in 1991.

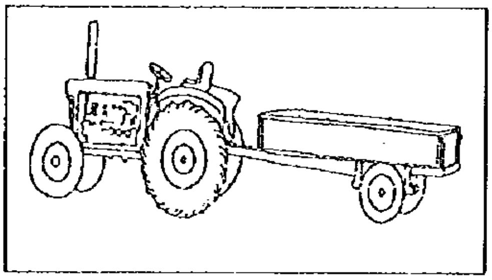
The density of commercial, "other", and institutional wastes, which are generated mainly in the city centre, only ranges from 30 to 50 kg/m^3 because they contain less kitchen waste. Streets in this part of DSM are usually narrow and bustling with traffic. The use of a compactor truck for the collection of these wastes in the city centre is recommended, as its small body can accommodate a huge amount of waste.

One of the potential problems associated with using compactor trucks will be maintenance. The maintenance of compactor trucks require a higher level of technological skill. According to our investigation, DSM is well equipped with the necessary skills to learn how to maintain compactor trucks in the future. The only problem is the absence of a modern workshop facility.

e.1.2 Non-Compaction Vehicles

There are many types of non-compaction vehicles, and these are generally distinguished by loading form. Some non-compaction vehicles have already been tested in DSM.

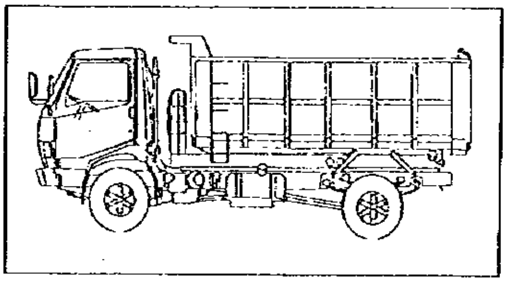
Tractors and Trailers



Tractors and trailers can be useful in certain areas close to the landfill. They can be useful when travelling over relatively rough terrain and can be used in connection with street sweeping services. The trailer can be parked at fixed locations where significant amounts of waste have accumulated over a certain period. For example, in areas where wastes produced from pruning trees have accumulated. One tractor could on this basis service several trailers in the course of a day.

These vehicles, however, are only useful for street cleansing in DSM and perhaps for the cleansing works of the Parks Department. They are not applicable to the routine collection of domestic waste because of the expensive tractor parking fees that would be incurred. The alternative -- manual loading of trailers from roadside dumps -- is not recommendable either.

Tipper Trucks



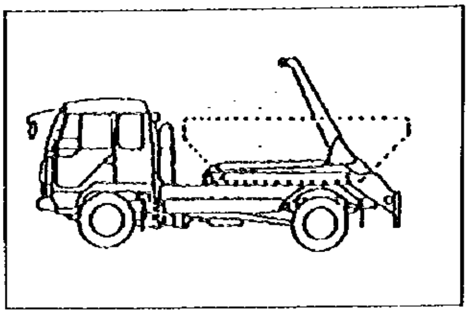
Tipper trucks are fairly basic and do not incur excessive maintenance costs.

Tipper trucks are effective for loading large heaps of waste with a wheel loader. However, the accumulation of waste heaps in the streets is neither environmentally-friendly nor economical. The use of tipper trucks is less productive because of the considerable time consumed for waste loading activities.

Loading is normally carried out manually, hence it is extremely slow and tiring due to the considerably high loading elevation (1.3 m at the side door of the present tipper truck in DSM). When loading, waste is handed over from the ground to the workers inside the truck who pack the load. Furthermore, the loading operation is unhygienic.

Aside from low productivity, the collection crew for this kind of operation demands higher wages than the crew for skip trucks. Therefore, this is not a recommendable system for DSM. However, because of its wide applicability and ease in maintenance, tipper trucks are favoured by private contractors and can therefore be an option.

Skip Trucks



A wide range of skip trucks are available, handling containers from 1 to 30 m^3. These trucks are highly productive since, with the 5 m^3 container previously used in DSM, they were able to collect about two tonnes of waste filled containers with each lift within a few minutes.

With the relatively short distance (10 km from City Centre) to the current DSM landfill, this system can accomplish between five and eight loads per day.

The skip truck itself is cheaper than a compaction truck and can achieve a higher payload in the course of a day than any non-compaction vehicles.

The containers may be manufactured locally, the system is robust and can handle a wide range of wastes. The vehicles are easy to maintain provided spare parts are available, especially for the container hoist system.

Container trucks have faster average road speed than tractor-trailers, and shall hardly affect the normal flow of traffic.

As well as providing a regular service from fixed collection points, this system is also equipped with functions that can deal with water accumulating at specific locations (markets) or resulting from particular public events. It, therefore, offers considerable flexibility in terms of dealing with the various wastes generated across the City.

The system was used satisfactorily for some time in DSM until the acquisition of spare parts became difficult.

The system is recommended for the future waste collection services in DSM, provided that a sufficient quantity of spare parts are purchased together with the trucks and that DSM is furnished with satisfactory facilities for their storage.

e.2 Railway Transportation

There are two railway lines running in DSM and both connect DSM and the western region. It is, therefore, not possible to use the railway for the transport of waste from the Kinondoni and Temeke districts. If the landfill site for the Ilala District will be located in the Pugu ward, waste may be transported by train via the railway line in this ward. Nevertheless, this method would be unrealistic in consideration of the unreliability of current railway services.

e.3 Water Transportation

Waste is transported to transfer stations for loading onto boats and is hauled to disposal sites. This method is frequently used for the disposal of residual soil of land reclamation works but cannot be adopted for DSM due to the absence of environmental preservation techniques crucial to this endeavour.

f. Transfer of Waste

Wastes discharged in transfer stations are hauled to the final disposal sites using large trucks (40 tonnes in capacity) to minimise overall transport costs. A transfer station is where wastes from collection vehicles of limited capacity are loaded into vehicles (or rail cars for rail transfer stations) of larger capacity for haulage to a disposal site.

The main purpose of using a transfer station is to reduce the net cost of transporting waste from collection areas to the final disposal site. The issue of whether or not to build and operate a transfer facility almost entirely depends on economic factors.

Although this system reduces transportation expenses, it requires additional cost for the construction of a transfer station, as well as for dumping and loading work. Accordingly, this system is not financially beneficial unless the disposal site is located far away.

The present disposal site in Vingunguti is located 10 km away from the city centre. Generally, the construction of a transfer station is considered to be impractical if the transport distance is less than 20 km (one way).

The distance of the proposed Kunduchi New MECCO quarry disposal site from the weighted centre is about 20 km. However, the average transportation distance is forecast to exceed 20 km from 2000 until 2002, when the site is planned (M/P) to accommodate all waste collected in DSM. On the other hand, the planned operation of two other disposal sites in 2003 will reduce the average transportation distance to the Kunduchi New MECCO quarry disposal site from the weighted centre of the waste collection area in Kunduchi district to about 18 km. The average transportation distance to the disposal sites in Ilala and Temeke will likely decrease, too. Therefore, no financial benefits can be expected from the introduction of a transfer station.

A simplified transportation system would be more reliable and productive, hence beneficial.

Five transfer stations employing antiquated haulage methods were used during emergency clean-up campaigns in DSM from 1992 until 1994. All of these stations were forced to close down due to the environmental hazards their improper operation has caused. The construction of another transfer station is, therefore, expected to meet strong opposition from the people, especially if DCC is to operate them.

As long as disposal sites are located within 20 km from the weighted centre of their respective collection areas, in compliance with this master plan, a transfer station will be unnecessary. Nonetheless, we recommend DCC to keep the matter under review in case the need for one arises in the future.

8.4.4 Street Sweeping System

a. Introduction

Street sweeping is one of the most visible of all government services. Consciously or not, residents allow their opinions of the effectiveness of street sweeping programs influence their assessment of the credibility of their municipal leaders and local officials. Visitors instinctively rate municipalities based on their external conditions, i.e., cleanliness. Dirty cities cannot attract foreign investors. These opinions should be positively used to stimulate the residents to build a better city.

Street sweeping programs were conducted mainly to remove litter and dirt so that streets appear presentable, and traffic will not create dust. In some areas particularly, regular street sweeping is necessary to prevent sewers from becoming clogged. It is also recognised that dirt is a potential pollutant.

Municipalities must balance the costs for adequate street sweeping and effective litter control programs, sewer improvement operations, projects to ensure safety of pedestrians and vehicle occupants, air and water pollution countermeasures, and economic development. Public education programmes alone, however, will not help eliminate street litter. Debris also accumulates from air pollution fallout, animal excreta, oil drippings, parts dropped from vehicles, spillage from solid waste collection, as well as mud tracked onto pavements.

b. Road Sweeping

Street Sweeping Methods

As practised today, street sweeping methods may be grouped conveniently under these general headings:

- manual sweeping
- mechanical sweeping
- vacuum sweeping
- flushing

c. Manual Street Sweeping

Manual street sweeping is by far the oldest method. However, it still retains certain advantages as follows:

Advantages

- low capital
- great flexibility of operation
- applicable to cleansing of areas where debris accumulation is most frequent
- makes cleaning beneath parked vehicles possible
- makes cleaning rough cobble stone pavements possible
- produces less noise
- creates more job opportunities
- requires minimum equipment repair and maintenance costs

Disadvantages

- difficulty in supervision
- dangerous under heavy traffic conditions

The equipment required for manual sweeping is simple and inexpensive. Sweepers use stiff bristled push brooms, wheelbarrows, shovels, and few other tools for special tasks.

d. Mechanical Sweeping

Mechanical sweeping entails the use of as many machines as possible, usually of various sorts. Three or four-wheel sweepers are mainly used for wide main roads. Self-propelled sweepers and water sprinkling-trucks are also used for mechanical sweeping.

Advantages

- great productivity
- low manpower requirement
- ensures safe operation

Disadvantages

- huge capital
- high maintenance cost
- low flexibility of operation
- difficult to conduct in narrow areas
- produces lots of noise
- difficult to conduct under heavy traffic

Mechanical Sweeping is generally the cheapest sweeping method for wide roads. This method is generally suitable for roads exceeding 6m in width.

e. Vacuum Sweeping

Vacuum street sweeping is becoming increasingly popular in developed countries because it removes fine materials as well as larger debris without using water, thereby curtailing water-use expenses. The flicking action of the broom is not as effective on fine materials as is the vacuum.

Vacuum units can also pick up larger debris, ranging from cigarette butts to beer bottles at operating speeds of 20 km per hour. With the help of gutter brooms, this unit is able to loosen and deflect debris so it can be picked up. It is also equipped with an additional broom, which may or may not be used in picking up debris, to windrow dirt. This second broom loosens the street dirt and pushes it toward the vacuum nozzles where it is drawn into the storage compartment. A filter system traps the dust and confines it to the sweeper hopper.

Advantages

- high sweeping capability
- no harm to sewage pipes by dust
- produces only a very small amount of dust

Disadvantages

- requires huge capital

- requires high maintenance cost
- low flexibility of operation
- difficult to conduct in narrow areas
- produces lots of noise
- difficult to conduct under heavy traffic

f. Flushing

Street flushers hydraulically move debris from the street surface to the gutter. Since the disposal of street dirt in sewers and catch basins is regarded with increasing disfavour because it pollutes the environment, several municipalities now flush only to aid sweeping and not as the sole method of sweeping.

Flushing before sweeping washes street dirt to the curb for collection by motorised sweepers. This type of flushing ordinarily employs smaller quantities of water and lower nozzle pressures to keep the dirt from flowing into the inlets as well as minimise the risk of getting pedestrians and vehicles wet. The benefits of flushing after sweeping are: cleaner pavements and the discharge of only small quantities of dirt into inlets and catch basins.

Advantage

- produces no dust

Disadvantages

- needs a large amount of water
- may clog sewage pipes
- requires high maintenance cost
- low flexibility of operation
- difficult to conduct in narrow areas
- difficult to conduct under heavy traffic

d. Current Street Sweeping System

DSM currently employs the manual sweeping method. The sweepers are usually women and they collect and heap up litters with a broom. The heaps are later picked up by refuse collection vehicles. Sand and dirt are generally collected with shovels and dumped at roadsides; only a small amount is transported to construction sites with trucks.

Street waste is largely made up of sand, and the roads in DSM were observed to produce a huge amount of sand.

e. Applicability to DSM

The flushing system is not at all suitable for DSM in view of current water shortages.

The mechanical and vacuum sweeping systems are also not suitable for DSM because they require large capital, and incur high operational and maintenance costs. The equipment used by these systems will not last long as the wastes swept from the streets of DSM contain a lot of sand.

Conclusively, manual sweeping is most suitable for DSM because of an abundant and inexpensive supply of labour force. The jobs that are produced by this sweeping system can contribute, albeit to a smaller degree, to the betterment of DSM's economy. This system is also flexible and can cope with waste containing lots of sand.

8.4.5 Intermediate Treatment System

This section considers the possible options for:

- The treatment of wastes by improving or removing some of its undesirable characteristics (e.g. to reduce waste volume, to render waste inert)
- The recovery of some of the wastes either as energy (gas, steam or electricity) or as usable materials (e.g. waste paper, ferrous scrap, compost)

Several criteria of prime importance in assessing the suitability and viability of any system of waste handling, treatment or recovery are as follows.

- Technical feasibility
- The degree to which the technology of the system is proven, i.e. "are these plants actually in operation elsewhere?".
- The reliability of the system and similar issues. (These questions are particularly important when considering latest technologies since, for example, many recovery systems are of relatively recent development).
- Its financial and economic implications: how much will the system cost to construct and operate; what are the potential benefits from savings in transport and disposal costs and from the sale of recovered products; what other economic benefits does the system offer in terms of foreign exchange savings, employment, etc. Of special importance here is the scope for actual selling and using any recovered products as this can frequently be less than is estimated.
- Its management requirements: how much qualified management and skilled labour will the system require to operate properly; how much cooperation will be obtained from the public, etc. Unless the necessary resources and skills are available, the system may be much less attractive than it initially appears.

Our assessment of the various operations below takes into account the prevailing conditions and problems in the study area, evaluating in broad terms the technical suitability and economic implications of different systems for handling, treatment and recovering solid wastes in DSM.

The following intermediate technologies are discussed in this section:

- Incineration
- Production of Refuse-Derived Fuel (RDF)

- Biogas Production
- Pyrolysis
- Composting
- Size Reduction
- Mechanical Sorting and Scavenging

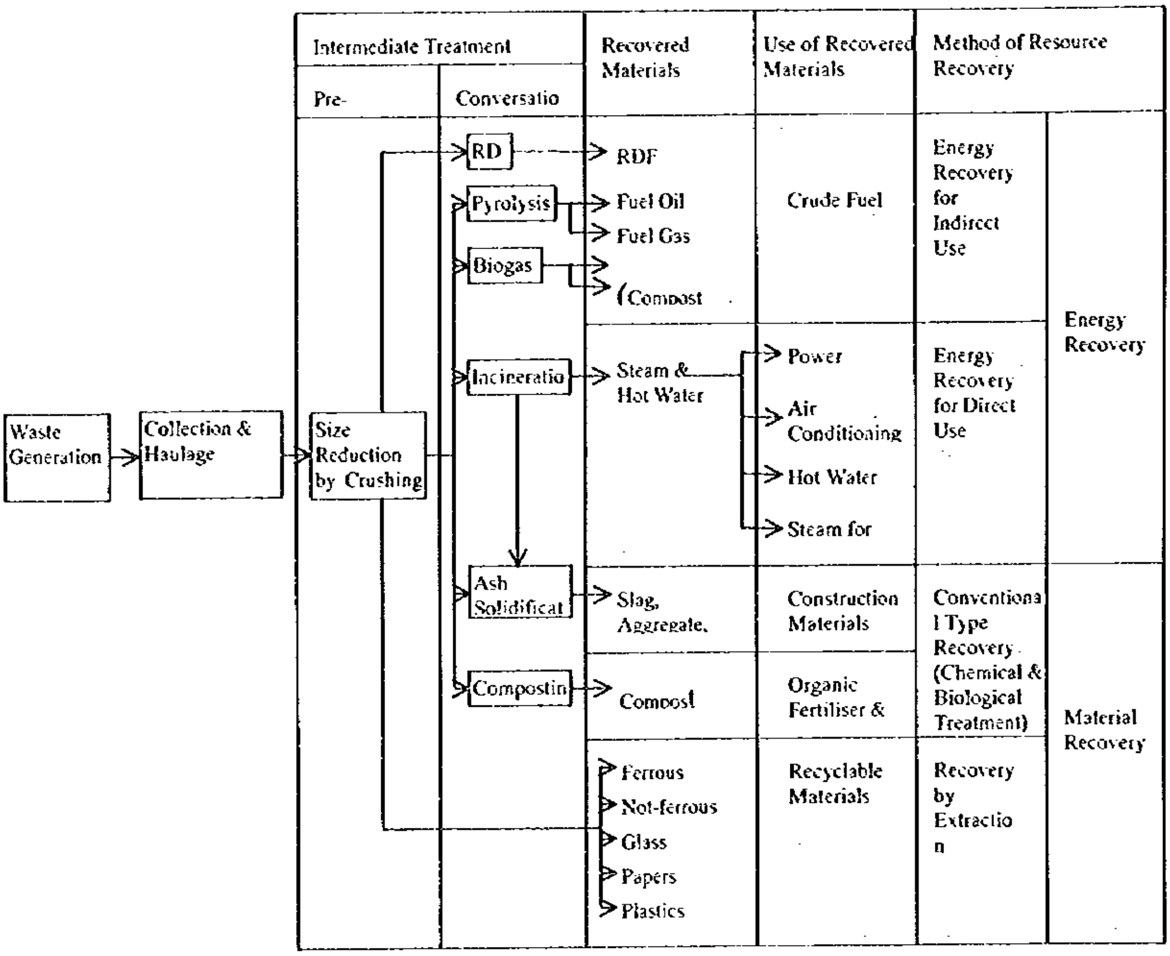


Figure 8-1: Intermediate Treatment Technologies and Resource Recovery Method

a. Incineration

Incineration of municipal solid wastes is one of the most popular method recently adopted for processing wastes in developed countries. Waste is mainly converted into stable oxidised gases and partly into stable inorganic matters by high temperature combustion. Of the various intermediate treatment technologies, incineration generally reduces waste volume to a large degree. It also stabilises putrescible organic wastes. Energy from waste incineration can be utilised for the production of electricity and/or district heating, and the income from the sale of energy may contribute to the economics of the plant.

A general observation would indicate that incinerators may be feasible where land for landfilling is scarce, expensive or very remote from the actual solid waste generation centre. Modern incineration and flue gas cleaning technology makes waste incineration an environmentally acceptable form of waste treatment, it is, therefore, possible to locate such plants even in densely populated areas. Accordingly, incineration has played a role in municipal waste management for more than 50 years in many major cities in Japan, Europe and the USA.

A modern incinerator consists of a number of basic components. Typically they include an unloading area, refuse feeding device, burning grate area, combustion chamber, air supply system, residue quench and disposal system, flue gas scrubber and water treatment system, and stack. Selection and design of these basic components will be the deciding factor in differentiating one incinerator from another.

Major differences in typical modern incinerators are noted in both refuse feed systems and grate designs. Feeding of refuse may be accomplished by either batch or continuous mode. Batch feed of refuse has experienced a decline in use over recent years in favour of continuous feed methods.

Applicability for DSM

One of the most important factors that would determine whether incineration is feasible is the calorific values of the waste being generated. It is said that the required calorific value of waste to burn without supplementary fuel is 1,700 cal/kg. According to the result of the waste composition survey, the calorific value of the waste generated in DSM could be estimated below 1,700 cal/kg due to little composition of combustible fraction. It will therefore require supplement fuel for burning.

The income from the sale of energy generated by incineration of waste, either by the form of heat or electricity, is often expected when it is introduced. To generate electricity by incineration of waste is not appropriate for DSM because it requires advanced technology not only for installation but also for operation and maintenance. Although to supply heat is easier in terms of technology, the demand for heat in DSM is estimated to be very small. Therefore, a large income from sale of energy cannot be expected.

A purpose-built automated incineration facility involves very high capital outlay. The technology is sophisticated and requires high levels of technical expertise to operate. Appropriate gas cleaning equipment needs to be installed and operational and maintenance costs are high. In addition, it requires continuous spending for support fuel. Therefore, both the investment cost and O & M cost are too expensive.

It is accordingly believed that incineration is inappropriate in DSM for technical and economic reasons.

b. Production of Refuse-Derived Fuel (RDF)

In this system the combustible fraction of the waste is separated by some mechanical or manual means primarily to extract the paper and plastic fractions which is then either used as its raw state or compacted into pellets.

The production of refuse-derived fuel can be done in several ways. In some of the earlier systems, raw refuse was first shredded to a nominal particle size of about 4 inches. More recent systems employ a rotary trammel before shredding. This trammel allows for prior separation of heavy, larger materials. After shredding, ferrous metals are separated magnetically for recycling. The remainder is then separated into a lighter, mostly combustible fraction and a heavier, mostly non-combustible fraction using an air classifier.

The lighter fraction is then further processed to produce the RDF through secondary shredding and screening. The RDF that is produced can be burned as a coal or a primary fuel in a specially designed boiler.

Today, RDF systems are mainly adopted in the United States and Canada. But the extensive use of this technology elsewhere in the world may not be recommendable due to the following problems observed.

- Occupational health problems at the plants specially at manual sorting lines.
- The pre-treatment plant is capital intensive leading to high waste disposal prices in order to make the pellets competitive with coal.
- The pellets still have a high content of pollutants (heavy metals and chloride) which conventional coal fired plants are not equipped for filtering.
- There is a need to alter the combustion conditions of conventional boilers and burners if a significant amount of RDF is to be burnt.

Advantages

- Combustibles in municipal waste can be converted to substitute fuel which can be stored and is easy to handle.

Disadvantages

- Waste which can be converted to RDF is very limited, and their availability can be found only in waste with a high paper content.
- The market for RDF will be limited due to the necessity of a special burner which can burn hard solid fuel such as coal.
- Some technical difficulties such as explosions in crusher, clogging in storing silo, etc., have to be solved.

The viability of this system would depend on the composition of the waste. In DSM the combustible fraction is very small and therefore such a system will not be viable.

c. Biogas Production

Biogas is the combustible gas developed when organic matter is degraded under anaerobic conditions, i.e. without the presence of oxygen. The energy will be bound in the hydrocarbon combination methane, which is the main element of natural gas. Anaerobic degradation of organic matter, resulting in biogas production, is an efficient means of degrading organic wastes, and making it hygienic.

Anaerobic waste treatment is a well known process relating to treatment of farmyard manure, sewage sludge and industrial waste water and other sludge. In the process, part of the organic material is transformed into carbohydrates, proteins, and fat by means of micro organisms. First the material is decomposed by certain bacteria to organic acids and carbon dioxide, after this process other bacteria decompose the organic acids and convert hydrogen to methane. Biogas can be utilised both for heat and power production. The residues are compost and can be utilised as a soil conditioner.

From a practical point of view, it is an advantage to place the biogas producing plant near a waste water treatment plant, in order to supply the biogas plant with water to dilute incoming wastes, and to supply power to the waste water treatment plant and achieve useful synergy.

It is possible to add the following wastes to biogas producing waste treatment plants:

- organic wastes from households, including meat and vegetables
- flowers, including herb wastes from gardens
- coffee grounds - tea leaves including paper filters
- fruit wastes
- paper kitchen towels and tissues
- organic sludge and waste water from industry, including the food industry
- sewage sludge

However, one should exclude waste water and wastes containing heavy metals, and wastes from some branches of the chemical industry.

Its advantages and disadvantages are summarised as follows:

Advantages

- resource recovery of wastes into potentially useful products, i.e., methane gas and compost
- minimal potential soil, water and ground water pollution
- possible location near urban areas

Disadvantages

- high investment cost
- only few years operational experience of municipal wastes
- transportation costs
- requires pre-sorting of organic wastes.

Applicability

The process of anaerobic digestion of animal manure and sludge from treatment of wastewater has a relatively long history (100 years or more). Experimental plants are being operated successfully in DSM. One plant uses slurry made from cow dung as raw material and another plant treats human excreta.

In Tanzania a feasibility study, "Takagas, 1993", has been conducted on the production of biogas and fertiliser from a range of wastes. The study has analysed different types of waste in the laboratory and found that waste especially from the sisal industry and the coffee industry seems promising as regards to anaerobic digestion. As the correct waste input is essential (i.e. organic waste only) for the operation of the plant, the study also stresses that it is neither the intention nor the objective of the Takagas project to solve the total waste problem in DSM.

This technology is in fact more appropriate for liquid waste rather than for heterogeneous waste like municipal waste.

While experimental anaerobic treatment plants have been built to digest municipal waste, to date these have not proved successful. A large-scale plant (capacity: 80 tons per day, price: 10 mill USD) constructed in Helsingor, Denmark operated for 4 years and then closed down in 1996 because of complaints from neighbours about foul door and because the technology required for the separation of municipal waste into organic waste and material was too expensive.

Biogas production using municipal waste is currently considered inappropriate for DSM.

d. Pyrolysis

Pyrolysis or gasification of waste involves the "cooking" of waste in a furnace in the absence of air. Depending on the way the reaction is controlled, oil, ashes, and gas are produced.

Pyrolysis is a process for breaking down organic substances by applying heat, in the range of 700-1,200 °C, in the absence of oxygen or at oxygen levels insufficient for total combustion. Under these temperature and pressure conditions, organic materials break down to shorter chain organic compounds and in some cases are reduced to charcoal, a carbon residue. A variety of potentially useful products may be produced, depending on refuse composition and operating conditions. Master products are charcoal, tar and pitch, light oil, organic acids, ammonium sulphate and combustible gases.

Theoretically, pyrolytic operations lend themselves well to a total recycling approach. Prior to the actual pyrolysis step, waste materials must go through a number of preparatory operations. Generally, solid wastes are first shredded, glass and metals are separated, and these materials are sold where an available market exists. Unusable residue, reduced to a small percentage of the original, is left for ultimate disposal at a sanitary landfill.

In the USA, the technology aims at recovery of storable energy, while in Japan it is being developed for non-pollution intermediate system for wastes.

Pyrolytic processing operations have the following advantages and disadvantages:

Advantages

- reduced land requirements for final disposal;
- reduction of solid wastes to a minimum volume;
- little air or water pollution (since little or no oxygen is involved, combustion products may not be a factor of pollution.);
- recycling of solid wastes into potentially useful products. Considering effective energy saving, production of such items as fuel oils, gas and steam are desirable and needed.

Disadvantages

- Large capital investment and high operation cost.
- The nature of oil or gas obtained from the facility is still insufficient for commercial use, therefore the market is limited to factory use only. The purification of oil or gas is cost intensive, and is not as effective as its cost may suggest.

Applicability

The first commercial pyrolysis gasification plant in Japan, which holds a capacity of 450 tons/day, started its operation in 1983. However, due to several accidents during its operation the plant underwent numerous reconstruction work. Another large scale plan is currently under way to improve the plant's energy recovery productivity, simplify the technologies employed, and curtail waste treatment cost.

The following statement was made on the use of pyrolysis in the United States: "The pyrolysis of municipal waste to produce a marketable oil or gas product has not been proven feasible. The pilot plants that were being developed for that purpose have been closed."

Pyrolysis is not a recently developed technology, but has been around in various forms for thirty years or more. However, since its role in the treatment of municipal solid waste is still theoretical, it is not suited to the conditions of DSM.

e. Composting

Waste composting is a method to achieve microbiological degradation of organic matter (household and vegetable wastes, garden wastes, etc.), to produce a recycled organic product for use in agriculture, gardens, parks, etc.

The most important technical issue about composting concerns the precise nature of the product. Compost is not a fertiliser but a soil conditioner. It does contain some plant nutrients but its value lies primarily in that it improves the soil structure by introducing humus, promotes microbial activities, and can help to retain fertilisers and moisture in the soil. Before being offered for sale, it is important that the product is sterile and free from pathogens that could be harmful to crops and people. To achieve this, it is important to control temperature and moisture content to enable the necessary stages of decomposition to take place correctly, in order to sterilise the product.

Most essential for achieving success when composting municipal waste is that the waste is sorted in a "green fraction" (i.e. organic waste) and in a fraction that is not appropriate for composting (plastics, glass, metals, etc.). Sorting may be conducted at a central composting plant (which would require mechanical equipment as well as manual sorting with due consideration of workers' hygienic conditions) or at the source (i.e. at the householders which would require a good deal of education).

The technology of composting municipal waste is well-established and operating experience and information is available in great detail. In spite of this wealth of experience, few of the refuse composting plants around the world are economically successful. The drawbacks commonly experienced with composting are its high cost and the low value of the compost products.

e.1 Waste Quality in DSM with reference to Composting

The most important factors that determine the quality of the finished compost are:

- The C/N ratio (Carbon/Nitrogen ratio) of the waste to be composted.
- The contents of unwanted materials (heavy metals, glass, and plastics) in the waste to be composted.
- Aeration and water content of the waste during the composting process.

These factors are briefly discussed as follows.

C/N-ratio

Experience has shown that the most favourable C/N-ratio of waste to be composted lies between 25 and 35.

- When the C/N-ratio exceeds 40, the duration of the fermentation becomes too long.
- When the C/N-ratio is too low (excess nitrogen), there will be loss of nitrogen.

At the end of the composting process the C/N-ratio should drop to below 20 and sometimes even to 15.

Three samples of market waste from Dar es Salaam were analysed in the laboratory. The average C/N-ratio was measured at 22. The samples indicated that the C/N-ratio should be raised by mixing e.g. with bundles of straw before being composted. Straw has a C/N-ratio in the range of 60-100.

However, at several markets it was found that the waste contain a lot of straw that had been used during transport as packaging of fruit and other materials. Therefore, it is expected that some market waste may have too high a C/N-ratio and needs to be mixed e.g. with chicken manure that has a typical C/N-ratio of 10.

Contents of Unwanted Materials

The waste from the markets of Dar es Salaam contains a relative low quantity of tin cans, bottles, and plastics.

However, to produce a high quality compost with a low contents of heavy metals and without bits and pieces of glass and plastics, these unwanted materials have to be removed before the waste is composted.

Aeration and Water Content

These are factors that have to be regulated during the composting process.

The objective of aeration is to supply the aerobic micro-organisms with sufficient oxygen and to permit the maximum exhaustion of carbonic gas. To allow sufficient aeration "chimneys" can be arranged in the heap and especially during the initial period of fermentation, when most carbonic gas is liberated, the heap must be opened and turned over.

After ventilation the most important factor remains water. An excess of it in the waste will cause the fermentation to be anaerobic especially in the lower part of the waste heap. It is estimated that in order to avoid this the waste must not contain more than 60 - 65 % of water. The ideal is around 55 %. Aerobic fermentation, however, cannot take place when the water content of the waste is lower than 30 %.

Conclusion Regarding Waste Quality

Visits to the larger markets, small neighbourhood markets, and high density areas clearly confirmed the large quantities of organic materials in the waste.

The waste from Dar es Salaam is clearly compostable, provided materials (plastics, glass, metals, etc.) not appropriate for composting are sorted out prior to composting.

e.2 Experience with Composting in DSM

Except for two simple pilot composting plants (community-based), no large scale composting plants have been operated in Dar es Salaam.

The pilot plants that were operated in Dar es Salaam are described as follows.

Pilot Composting Plant at Ardhi Institute

A pilot composting plant was constructed in 1985 at the Ardhi Institute. The plant facilities comprised a concrete slab (5 x 10 m) covered by a roof to prevent wetting of materials. Raw materials used for the composting process was organic waste from the institute's canteens etc. The plant was operated during a period of approx. 1 year, applying manual labour force for waste collection, sorting, watering and aeration/turning of windrows.

In the report that was prepared by Mr. M. Yhdego, Ardhi Institute, 1993 it was concluded that mature compost was produced within 22 days. The observed C/N-ratio (in the order of 12) indicated a high quality compost without bits of glasses or plastics, had been produced.

Further, the report concludes that composting is an alternative to dumping, if it is well managed, decentralised and community-based. Complicated mechanised and centralised composting plants are assessed to be inappropriate for Tanzania.

Pilot Composting Plant in Vingunguti

The plant started its operation in March, 1996 with financial assistance from HABITAT who supported its operation until the end of August, 1996.

The layout and operation of the plant was very similar to the plant that was operated at the Ardhi Institute and the plant was operated with the advice of Dr. M. Rubindamayugi, University of Dar es Salaam.

The plant was operated on a community-basis. Four labourers and one watchman were employed and each paid 30,000 Tsh/month. Also, HABITAT was supplying materials for the composting process (lime, chicken manure, and saw dust) and bags (150 Tsh/bag) for transport of the compost.

The employees of the composting plant collected waste from 30 households free of charge. The waste was collected on a daily basis employing small (0.2 m^3) handcarts due to the very rough road conditions of the area. It was intended that the plant should had served more householders and that these should pay for the services.

At the composting plant the waste was sorted and large organic items were cut into smaller pieces with a panga. The waste was stockpiled in an approx. 1.5 m high heap. Water was added, and also lime, chicken manure, and saw dust. The heap was covered with sacks to prevent drying out of the waste. The waste heap was turned 3 or 4 times before the finished compost was obtained after only approx. 3 weeks.

Most of the compost was given away for free to members of the community who used it in their gardens. People that were questioned were satisfied with the product. Some even claimed that it was better than chicken manure. Part of the compost was taken to the University who tried to promote the compost amongst farmers.

HABITAT stopped its financial support to the composting plant in August 1996 and when this study stopped buying compost at the end of November 1996, the composting plant stopped its operation.

It was argued that the plant might have been sustainable if:

- The transport costs to the farmers had been less. Thus, the plant should have been located near an allotment.
- The farmers required education. They should be aware that compost is not a fertiliser but a soil conditioner, and that compost should not be compared with chicken manure.

e.3 Alternative Composting Methods

Despite the incessant announcements of breakthrough innovations in the technology of composting, all major economically feasible advances are thought to have been made. The so-called breakthroughs are either a minor modification of existing systems or the utilisation of mechanical devices unrealistically expensive either in capital or in operating costs, or in both.

Several composting methods are used and many more have been tested at the pilot scale. The most common composting methods are the following:

- Centralised composting plants using open-air fermentation in windrows.
- Centralised composting plants using some kind of digester before being placed in windrows.
- On site composting using the windrow system.

All composting plants require the removal of non-compostable materials like metals, plastic, glass, stones, etc., prior to composting. Although not all such materials will be removed, this process will keep their concentrations in the finished product at a low and acceptable level .

The composting plants are briefly described as follows.

Centralised Windrow Composting

After sorting and before being placed in windrows, the waste is grinded e.g. in a hammer-mill and the water content is adjusted to the optimum weight level of approximately 55 %.

The homogenised waste is placed in windrows which are approximately 2m high, for a period of up to 9 weeks. Every 2-3 weeks the windrows are turned and during this process the water content is adjusted. The operator must make sure that all materials in the windrow are exposed to its high temperature by checking whether materials previously on the surface of the windrow shift to the central part after turning. Turning can be performed either by front-end loaders or by special turning machines.

Depending on the final application, the mature compost may be sieved using screens with coarse or fine meshes.

Cost estimate for a plant (capacity: 75 tonnes/8 hours) equipped with open-air windrow composting techniques including sorting facilities is presented below based on the 1996 price level:

Construction costs:	*3,000,000 USD*
• Buildings	200,000 USD
• Paved areas and drainage	900,000 USD
• Mechanical and electrical installations	400,000 USD
• Running equipment	800,000 USD
• Design, procurement, and supervision (10%)	200,000 USD
• Miscellaneous (20 %)	500,000 USD
Operation costs	*300,000 USD/year*

- Salaries
- Power, water, fuel, etc.
- Disposal of residues
- Maintenance (7 % of construction costs)

The possible income from sale of compost (approx. 30 tonnes/day) is not included.

Centralised Digester/Windrow Composting

After the sorting process, the compostable part of the waste is treated in a mechanical digester to provide optimum conditions, and hence accelerate the composting process.

A number of mechanical digesters are available in the market. Probably one of the more successful is the Dano-drum. This system involves the use of a large, slowly rotating drum and the required grinding, watering and aeration of the waste takes place in the horizontally rotating drum furnished with knives. Material is injected in one end and after one to three days of slow rotation is ejected from the opposite end of the machine where the material is sieved by a coarse screen. Air is injected into the interior of the drum to ensure constant supply of oxygen. The water may be subsidised by wet sewage sludge, increasing the nutrient content of the finished compost.

The homogenised waste is placed in windrows for a period of 1 to 2 months - one month if the material is turned occasionally.

Cost estimate for a pilot composting plant (capacity: 50 tonnes/8 hours) equipped with the combined Dano-drum/open-air windrow system including sorting facilities is presented below based on the 1996 price level:

Construction costs:	*6,000,000 USD*
• Buildings	500,000 USD
• Paved areas and drainage	700,000 USD
• Mechanical and electrical installations	2,600,000 USD
• Running equipment	800,000 USD
• Design, procurement, and supervision (10%)	400,000 USD
• Miscellaneous (20 %)	1,000,000 USD
Operation costs	*500,000 USD/year*

- Salaries
- Power, water, fuel, etc.
- Disposal of residues
- Maintenance (10 % of construction costs)

The possible income from sale of compost (approx. 20 tonnes/day) is not included.

On Site/Community-Based Composting

Composting is a natural process which does not require sophisticated equipment. Any farmer or garden owner may produce compost by turning and watering a pile of organic wastes.

The pile must be sufficiently large to avoid rapid drying-up and small enough not to turn anaerobic. The pile must be mixed thoroughly at least once a week depending on the actual climatic conditions after which it may be used as a soil conditioner or as a fertiliser when mixed with manure or sewage sludge.

A community-based composting unit is presently being operated at Vingunguti Village, DSM. The plant facilities comprise a roofed concrete slab (5 x 10 m) to prevent materials from getting wet. Four labourers are employed to undertake waste collection using small handcarts, sorting and grinding works, watering and turning of windrows. The plant produces mature compost virtually free of glass or plastic in a period of 3 weeks.

Cost estimate for a community-based composting unit like the one at Vingunguti Village (capacity: 100 kg /4 hours) is presented below based on the 1996 price level:

Construction costs: *5,000,000 Tsh*

- Concrete slab (5 x 10 m) with block foundation
- One wall made of concrete blocks
- Steel plate roof for wooden structure
- Hand tools (forks, shovels, etc.) and protective gears
- small (0.2 m^3) handcart

Operation costs *1,000,000 Tsh/year*

- Salaries (2 workers)

- Water, lime and other materials for composting
- Bags for transport of compost

The possible income from sale of compost (approx. 50 kg/day) is not included.

e.4 Market for Compost

The results of compost market survey conducted in this study, described in section 4.3, are summarised below.

- Most farmers were willing to use the compost when supplied to them for free. However, some farmers (5%) rejected the compost that was produced from waste because they were afraid that the compost would spread diseases to their vegetables.
- The compost was generally found to be less fertile than chicken manure.
- The farmers were reluctant to state the price that they were willing to pay for compost. Generally, it was stated that the price should be lower than the price for chicken manure (200 Tsh/70 litters, excluding transport).
- Presently, the farmers use chicken manure for improving their soil. They would be extremely reluctant to use compost produced from waste, unless it could be given to them for free.
- DCC will not require compost for improving the parks in the near future.

e.5 Recommendations on Composting

The use of a centralised, large mechanical composting plant like the ones adopted in Japan, Europe, and the United States, is currently considered inappropriate for the City of Dar es Salaam. They are not only extremely capital intensive, but also require high operation costs as well as a highly skilled labour force.

The introduction of decentralised, community-based small composting units may be feasible if the City Council's SWM-services are not extended to low income areas. This community-based composting method would be very appropriate for these areas, and would enable an environmentally sound way of disposing organic waste. At the same time composting converts the organic content of refuse into compost to improve the fertility of agricultural soils.

f. Size Reduction (Crushing and Shredding)

A size reduction facility is normally equipped with crushing and shredding functions, and is generally used as a pre-treatment facility of an incineration plant, composting plant and other intermediate treatment facilities. It is also used to improve sanitary landfill operations.

Shredding reduces the volume of waste to be transported to the final disposal site for sanitary landfill operations. Shredded waste settles more quickly than unshredded waste, making the landfill sanitary and less subject to complaints from nearby residents. This condition also ensures fewer spontaneous combustion during landfill operations. Because this condition produces fewer rodents and insects, less insecticides and pesticides shall be required.

Shredded wastes cause less damage to the landfill equipment and trucks than unshredded waste, and has a high compaction rate.

The term "crush" has various meanings, i.e., shredding, milling, pulverising, grinding, cutting, tearing, ripping, etc., for which appropriate machines are developed.

An ordinary hammer mill with a swing hammer attached to the horizontal or vertical shaft rotates very fast. Waste is dumped from above, and discharged from the opening at the bottom after it is pulverised by the shearing force of the cutting board.

The grindability of a machine depends upon the substances to be crushed and the size required by the treatment system. The pulverising process will be accompanied with sieving, if necessary.

Advantages and disadvantages

Advantages of shredding and crushing are listed below.

- Shredding and crushing (size reduction) contribute to the work efficiency of other intermediate treatment facilities.
- It is well adapted to the local conditions and intended plans because (1) shredding reduces volume by about 50%, thus making transportation easier and more efficient, and (2) shredded waste spreads more easily. Shredded waste is compacted better in the sanitary landfill and takes up less space making the landfill area last longer.
- Shredding and crushing produce a more compact and ultimately more stable sanitary landfill, hence raising the post-closure value of the land.
- Since shredding and crushing facilitate waste compaction, ensures fewer spontaneous combustion and propagation of fewer flies and rodents during landfill operations, particularly if solid waste disposed receives a final cover.
- Shredding and crushing definitely increase compaction, making landfills denser and reduce the percentage of settlement.

Shredding and crushing have the following disadvantages.

- The use of the rotary type hammer crusher consumes large amount of electricity as it usually requires a high powered electric motor.
- Damage due to explosion caused by flammable matters in waste might occur frequently. Therefore, strict checking and sorting out of dangerous matters have to be done.
- Frequent repair works or replacement of damaged parts shall be necessary for the tremendous wear and tear of mechanical parts such as hammer beaters, shear blades, etc.

Applicability

This system is useful when used with other intermediate treatment technologies. However, this will increase trouble in operation and maintenance. Since a simple technical system is appropriate for DSM this system is not recommendable.

g. Mechanical Sorting / Scavenging

Mechanical sorting and scavenging are inexpensive technologies used to recover as much valuable materials as possible from waste generated without causing any secondary environmental pollution.

Metals, non-ferrous metals, papers, cardboards, glass, plastics, rags, leather are separated manually or by use of an air classifier or a magnetic separation equipment, depending on their respective characteristics. Air for the operation of an air classifier can be supplied by low-pressure blowers or fans.

Advantages

- With the existence of various sorting devices such as pneumatic, mechanical, and magnetic separation equipment, sorting is effectively executed under hygienic conditions.
- Many sorting systems are relatively simple and easy to operate.
- These sorting systems require comparatively cheaper investment, utility cost, and maintenance cost.

Disadvantages

- This system does not contribute to the compaction of waste as its use is generally limited to relatively dry wastes with rich inert material content.
- Objects rejected after usable materials are sorted have to be re-hauled to the landfill site.
- The materials obtained by mechanical separation are generally of inferior quality in comparison to materials manually sorted out. For example, with the pneumatic device, materials recovered are usually a combination of light fractions, e.g. plastic and paper. Each fraction cannot be completely separated because the specific gravity of both materials is almost equal to the specific weight.
- Manual sorting puts the workers at risk due to the possible inclusion of infectious or hazardous wastes.

Applicability

As indicated earlier in this report there are very few fractions left in waste for disposal that could be salvaged and marketed, especially since waste in DSM is highly organic and therefore only suitable for nothing else but composting.

The separation and reuse of waste in highly industrialised countries, which contains paper, metals, glass, and plastics in comparison with DSM, only involves a marginal cost.

Conclusively, the informal scavenging sector in DSM should be allowed to salvage what components it can from the waste and that no formal involvement on the part of the City Council is necessary.

h. Conclusion

No intermediate treatment technology is recommended for DSM in view of the city's current conditions. On-site/community based composting system may be adopted if there is a demand for compost in the area. Promotion of on-site/community based composting for private use and not otherwise may be a suitable means of promoting self disposal. The sale of compost as a soil conditioning agent require further detailed market research.

Table 8-3: Characteristics of Possible Intermediate Treatment System

			Contribution to Landfill			Special Cautions								
ITT	Recovered Material	Main Target of System	Volume Reduction	Harmless	Stabiliza-tion	Stability of Technology	Pre-treatment	Post treatment	Rejected Sub-stances	Acceptability of Refuse Quality	Construction Cost (US$/ton)	Marketability of recovered Material	Environmental Impact	Remarks
Incineration	Heat/or Electric Power	Volume Reduction & Energy Conversion	B	B	B	A	Not Necessary	Not Necessary	Non-combustibles	A	82,200*1	(Electricity or Heart) C	B	- Initial/Running Cost - Possibility to find User of Heart
RDF	Solid Fuel	Conversation to Fuel	C	C	C	C	Necessary	Necessary	Non-combustibles	C	N.A.	?	C (Noise & Dust)	- Marketability of Products
Biogas	Gas & Compost	Conversation to Fuel & Fertilizer	C	C	C	C	Necessary	Necessary	Glass, Stone, Plastic, etc.	C	97,500*3	C	B	- Stability of Market for Products
Pyrolysis	Gas or Oil	Conversation to Fuel	B	B	B	C	Necessary	Necessary	Non-combustibles & Carton	C	N.A.	X	B	- Incompletion of Technology - Initial/Running Cost
Composting	Compost	Conversation to Fertilizer	C	C	C	A	Necessary	Necessary	Glass, Stone, Plastic, etc.	C	46,000*2	C	C (Odor)	- Stability of Market for Products
Ash Solidification	Slag	Volume Reduction & Prevention of Waster Pollution	A	A	A	C	Occasionally Necessary	Not Necessary	None	B	N.A.	?	B	- Large Consumption of Supplement Fuel - Difficulty of Operation
Size Reduction (Crushing & Shredding)	Ferrous etc.	Volume Reduction of Bulky Waste	C	C	B	B	Extraction of Explosive Object	Necessary	Discarded Material	C	N.A.	C	C (Noise & Dust)	- Large Consumption of Electricity - Much Expense for Maintenance - Possibility of Explosion
Sorting (Mechanical or Manual sorting)	Ferrous, Glass, Paper, Plastic, etc.	Recycling	C	C	C	A	Occasionally Necessary	Necessary	Discarded Material	C	N.A. 46,000*4	B	B	- Stability of Market for Salvaged Materials

Note : A: Excellent B: Good C: Fair of ( ) to be considered D: Poor and ( ) shows reason
ITT: Intermediate Treatment Technology.
*1 : The cost for 30 ton/hour plant was estimated in the Study on the Solid Waste Management for Poznan City, May 1993 JICA (JICA Poland SWM Report)
*2 : The cost for 19,000 tonnes of garden waste per year from the JICA Poland SWM Report
*3: The cost for 36,000 tonnes per year from the JICA Poland SWM Report
*4: The cost from the JICA Poland SWM Report for 20,000 tonne/year

8.4.6 Recycling

a. Introduction

Most developed countries started taking various actions in the mid-1980s directed toward recycling of solid waste. The commonly accepted definition of solid waste recycling would be to utilise one or more waste components in such a way that they are not deposited in a landfill. Materials commonly recycled or recyclable wastes are paper, cardboard, glass, bottle, aluminium, ferrous metal, and plastic.

The primary benefits of recycling are conservation of natural resources and landfill space; however, the collection and transport of materials requires substantial amounts of energy and labour, and historically, most recycling programs are subsidised economically[5]. The requirements for a successful program are that a strong demand exist for recovered materials and that the market value of the materials be sufficient to pay for collection and transportation costs.

b. Present Situation of Recycling in DSM

b.1 Composition of Recyclable Waste

Table 8-4 shows the surveyed waste composition of DSM, the standard waste composition of industrialised countries and the United States. This comparison clearly shows that the present composition of recyclable waste in DSM is far less than that of industrialised countries: 12 % for DSM, 27-80 % for industrialised countries, and 67.5 % for the United States.

Table 8-4: Comparison of Waste Composition

	DSM in 1996	Industrialised Countries	United States in 1990[b]
Kitchen	45.03 %	20-50 %	9.0 %
Paper	4.07 %	15-50 %	40.0 %
Textile	1.10 %	2-10 %	2.0 %
Plastic	2.01 %	2-10 %	7.0 %
Grass/Wood	25.11 %	-	20.5 %
Leather/Rubber	0.71 %	-	1.0 %
Metal	1.65 %	3-13 %	9.5 %
Glass	2.90 %	4-12 %	8.0 %
Ceramic/Stone	0.33 %	1-20 % (including others)	3.0 % (including others)
Others	17.09 %	-	-
Total	100.00 %	100.0 %	100.0 %

Note: Screened items are recyclable wastes.
Source:
[a]: "Integrated Resource Recovery, Recycling form Municipal Refuse: A state-of-the-art Review and Annotated Bibliography", UNDP Project Management Report Number 1, S. Cointreau, et. al. 1985
[b]: Integrated Solid Waste Management, Engineering Principles and Management Issues, G. Tchobanoglous, et al, McGraw-Hill, 1993

[5] Integrated Solid Waste Management, Engineering Principles and Management Issues, G. Tchobanoglous, et al, McGraw-Hill, 1993

b.2 Paper

The comparison of the amounts of waste paper (2,160 tons/month from WACS generation sources as well as large quantities from commercial printers) collected by middlemen (360-520 t/month) and the estimated industrial demand for paper in DSM (100-200 t/month) shows that there is no demand for paper recycling in DSM.

There are two paper factories using waste paper as raw material in DSM: Kibo Paper Industry and Tanpak Industry Ltd. Because the market demand is small in DSM, however, some are transported to factories in Moshi and even Nairobi. Although this incurs high transportation costs, it proves the importance of recycling paper in view of its usefulness in other areas.

On the other hand, because the demands of these reprocessing industries for waste paper considerably vary, as was observed in June-July 1996 when interviewed middlemen had large stockpiles of waste paper mainly because these industries were not buying any, it is vital to stabilise market demand prior to expanding paper recycling activities.

b.3 Metal

There is a sufficient market demand for metal recycling in DSM, with six large metal industries and quite a number of micro-industries using metal waste as raw material. Almost all metal wastes collected in Tanzania are transported to these large industries, while the micro-industries use metal wastes for making products like kerosene lamps.

Metal waste recycling is infeasible in DSM, however, since the ratio of generated metal waste to the total waste is only 1.65% -- this is because the major generators of metal wastes are industries and not households.

b.4 Glass

The deposit system adopted to ensure the return of bottles, especially beverage bottles, has been very effective with a turnover rate of about 99 %.

Kioo Ltd., is the only company in DSM producing bottles out of broken glasses. It consumes 200 tons of broken glasses a month, an amount equivalent to 20 % of its total production. This study concludes a potential market demand for glass recycling in DSM as survey results indicate a possible increase in demand for broken glasses.

b.5 Plastic

There are no plastic recycling or reprocessing plants in DSM.

c. Alternatives

Recycling systems may be divided into two types in terms of the magnitude of involvement of governmental organisations: government related recycling system and private sector centred recycling system.

c.1 Government Related Recycling System

Government related recycling system are carried out as a means of economically controlling solid waste generation. This system obliges dischargers to conduct waste segregation and sorting, as well as separate discharge, collection and transportation.

Although these activities incur additional costs they reduce the amount of waste for final disposal.

Many industrialised countries suffer from landfill site scarcity problems. In Japan, wastes are often transported to disposal sites more than 500 km away from the weighted centres of collection points. Therefore, this system has become particularly common in industrialised countries as it generates considerable financial benefits by saving landfill space and reducing transportation costs.

Although government related recycling system is considered to be more productive, they incur large collection and transportation costs, and their success is heavily dependent on public cooperation. Further, because conditions prevalent in developing countries entirely differ from those in industrialised countries, the implementation of this system in the former could generate a different outcome. Therefore, this alternative is only recommendable for municipalities where solid waste management unit cost is very expensive. And this is not the case in DSM.

c.2 Private Sector Centred Recycling System

The government has an indirect and limited role in the promotion of this recycling system, that is the conduct of public education programmes on recycling. This system does not impose separate collection and any risk encountered is solely the responsibility of the private entities involved.

This alternative is suitable where risks and uncertainties associated with recycling are large and where the benefits could be nothing more than the additional cost this activity incurs. Accordingly, this system is recommended for DSM.

d. Conclusion

Recycling in DSM may be summarised as follows:

- Recyclable wastes only constitute 12 % of the total waste amount.
- There is enough market demand for metal and glass.
- Market demand for paper waste is limited and unstable.
- Micro enterprises actively recycle waste materials for private and commercial use.

Generally, individuals and enterprises involved in recycling businesses often languish over the cheap market prices of recyclable wastes which cannot usually compensate for the collection and transportation costs. Even in Tanzania, collection and transportation cost is a problem. Therefore, recycling is usually carried out only in a small scale in DSM where micro enterprises actively recycle waste materials for private and commercial use. The collection and transportation cost incurred by the recycling activities of these enterprises is not expensive because they conduct their work within the confines of DSM or even their wards. Accordingly, the main reason why collection and transportation costs are expensive is the limitations in the business to go out of their territories in search of recyclable materials.

As demands for glass and metal wastes are foreseen to escalate in DSM there is a need to curtail collection and transportation costs or acquire financial subsidies to expand present recycling activities.

In DCC, financial stability and the improvement of sanitary conditions take precedence over environmental protection. Therefore, DCC is basically recommended not to take any steps toward recycling that would only involve a lot of capital. DCC should, however, start promoting recycling by source separation and discharge to control the rapid waste generation growth rate. Since it would take considerable time before the residents can adequately implement source separation and discharge, these activities should be introduced as early as possible regardless of whether the resulting wastes can be collected and transported separately.

8.4.7 Final Disposal

a. Possible System Alternatives

Upon consideration of the possible system alternatives for final disposal, the following aspects are to be taken into account:

- location and number of final disposal sites
- final disposal methods
- landfill structure
- level of sanitary landfill development and operation

b. Location and Number of Final Disposal Sites

The districts of Kinondoni, Ilala and Temeke should have their own disposal sites for the disposal of their respective wastes.

c. Final Disposal Methods

The final disposal methods can be divided into the following three types:

- open dumping
- controlled tipping
- sanitary landfill

Although the open dumping method is generally employed in the Vingunguti disposal site, this operation shall be terminated in view of its adverse effects on landscape, public health and the environment.

Sanitary landfill should be adopted as it has been proven to be the most economical final disposal method in terms of controlling environmental impacts within the acceptable level.

The advantages of sanitary landfill are as follows.

- Where land is available, sanitary landfill is usually the most economical solid waste disposal method.

- Sanitary landfill is not investment intensive compared with other disposal methods, i.e., composting and incineration.
- In contrast to incineration and composting, sanitary landfill does not require additional treatment or disposal operations for residue, quenching water, unusable materials, etc.
- A sanitary landfill can receive all types of solid wastes, eliminating the necessity for separate collections.
- A sanitary landfill is manageable; increased quantities of solid wastes can be disposed of with a minimum number of personnel and equipment.
- Submerged land may be reclaimed for use as parking lots, playgrounds, golf courses, botanical gardens, etc.

d. Landfill Structure

There are five types of landfill structure as shown below.

- anaerobic landfill
- anaerobic sanitary landfill
- improved anaerobic sanitary landfill
- semi-aerobic sanitary landfill
- aerobic sanitary landfill

Either of the above landfill structures contribute to the mitigation of environmental pollution. Figure 8-2 illustrates each of the above landfill structures.

Anaerobic landfill

As leachate generated in landfill layers is hardly drained, the landfill layers constantly maintain anaerobic condition. The quality of leachate is very poor, causing bad odour and propagating vectors and vermins.

Anaerobic sanitary landfill

Covering soil is applied on each layer of waste thereby preventing the outbreak of bad odour and incidental fires, and the propagation of harmful insects to a certain extent. However, leachate and gas generation problems remain.

As in anaerobic landfill, the landfill layers maintain anaerobic conditions.

Improved anaerobic sanitary landfill

In addition to covering soil, this landfill structure is constructed with a leachate drainage facility at the bottom of the disposal site. Leachate quality is improved and anaerobic conditions are maintained.

Semi-Aerobic sanitary landfill

Leachate quality is favourably improved with constant drainage. Drainage pipes stimulate natural ventilation, achieving aerobic conditions in the landfill layers and consequently accelerating solid waste decomposition.

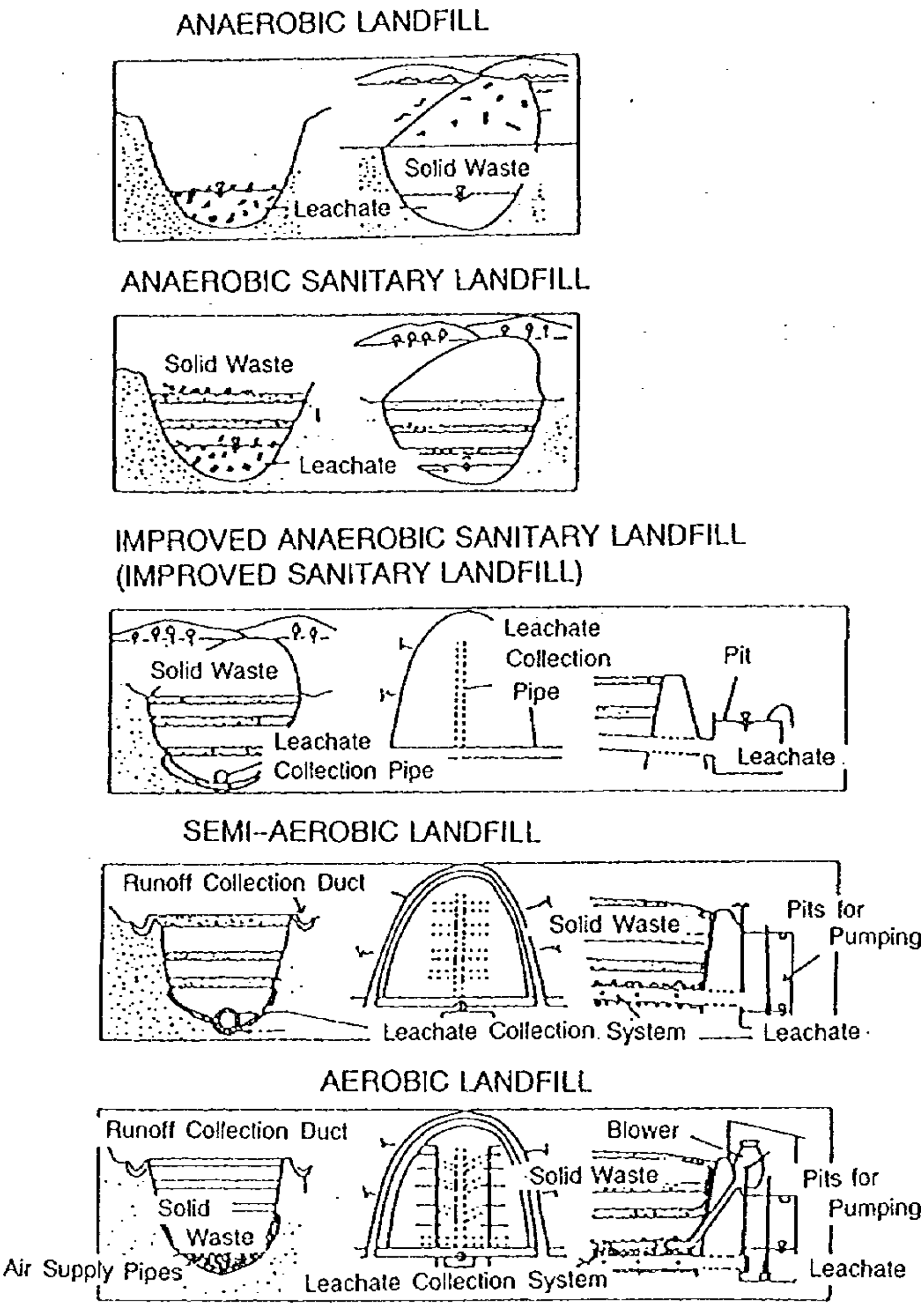


Figure 8-2: Landfill Structures

Aerobic sanitary landfill

In addition to the drainage pipes used in semi-aerobic landfills, air supply pipes are introduced for forced air injection to achieve aerobic conditions in the layers, thereby accelerating solid waste decomposition and stabilisation and improving leachate quality.

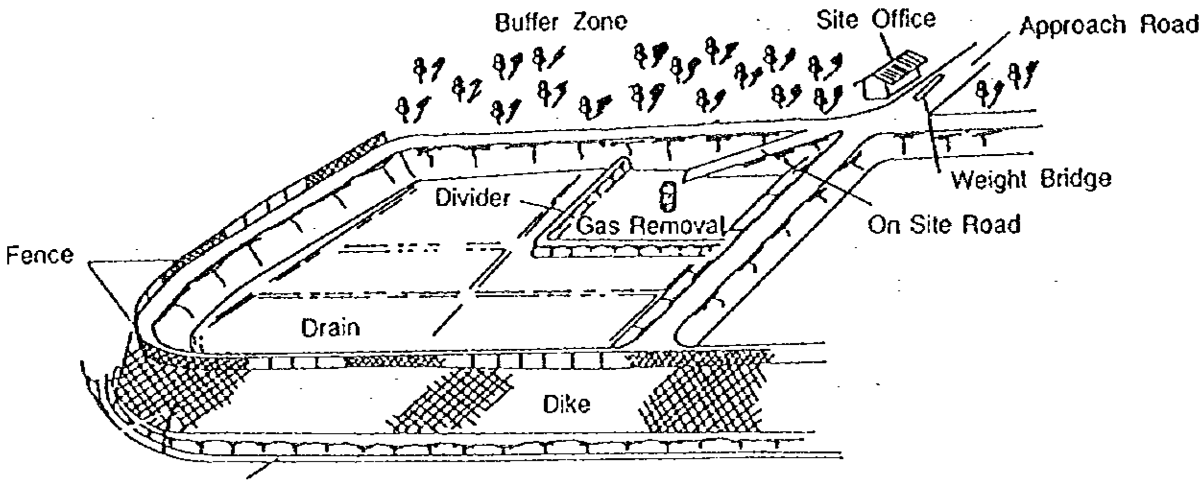
In view of the above advantages and disadvantages, the final disposal sites proposed in the Master Plan shall have a semi-aerobic sanitary landfill structure with leachate drain pipes.

e. Level of Sanitary Landfill Development and Operation

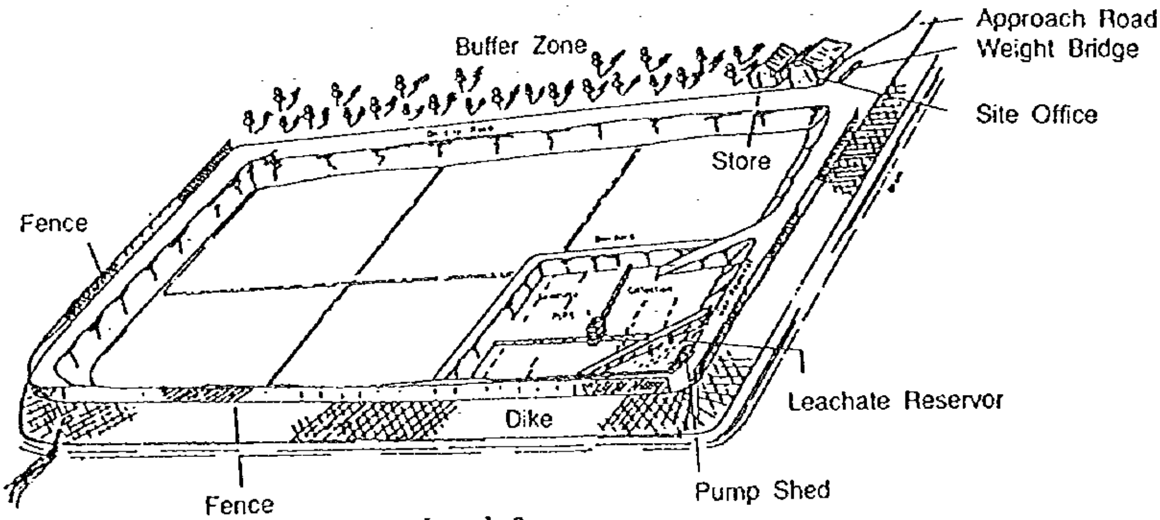
The sanitary landfill development and operation levels are classified as follows:

- Level 1, Controlled tipping
- Level 2, Sanitary landfill with bund and daily soil covering
- Level 3, Sanitary landfill with primary leachate circulation system
- Level 4, Sanitary landfill with leachate treatment system

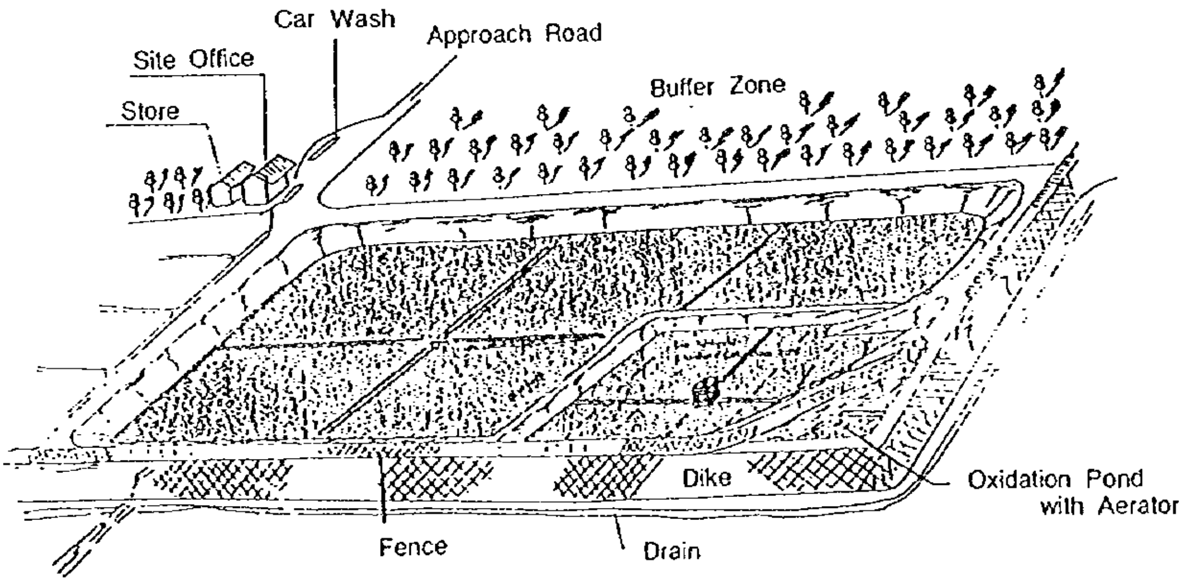
The prospective sanitary landfill development and operation levels are illustrated in Figure 8-3.



Level 2



Level 3



Level 4

Figure 8-3: Illustration of Prospective Sanitary Landfill Development and Operation Levels 2, 3 and 4

The above mentioned sanitary landfill development and operation levels are described below.

Level 1: Controlled Tipping

Introduction of controlled tipping through:

- establishment of access to site;
- provision of cover materials for the prevention of fire outbreaks and the dispersion of rank odour;
- establishment of inspection, control and operational recording system for incoming waste.

Level 2: Sanitary Landfill with Bund and Daily Soil Covering

Introduction of sanitary landfill through:

- establishment of disposal site boundary to eliminate scavenging;
- execution of sufficient cover over waste disposed;
- enclosing the disposal area with a bund;
- construction of a divider between present and future landfill areas;
- establishment of a drainage system in order to divert storm water flow from surrounding areas away from the disposal site and to reduce leachate;
- construction of environmental protection facilities, such as buffer zone, litter control and gas removal facilities, to abate direct impact on surroundings;
- installation of gas removal facilities to achieve the conditions necessary for a semi-aerobic sanitary landfill;
- introduction of amenities for staff.

Level 3: Sanitary Landfill with Leachate Circulation

Establishment of leachate control through:

- installation of leachate collection, circulation and monitoring facilities;
- installation of liners for seepage control;
- construction of semi-aerobic sanitary landfill to accelerate waste decomposition and facilitate stabilisation;
- introduction of water sprinkling for dust prevention.

Level 4: Sanitary Landfill with Leachate Treatment

Establishment of leachate treatment through:

- installation of an oxidation pond;

The above mentioned sanitary landfill development and operation levels are described and tabulated in Table 8-5. Table 6-7 shows the environmental standard each landfill level has to meet.

Table 8-5: Outline of Sanitary Landfill Development and Operation

	Items	Level of Sanitary Landfill				Remarks
		1	2	3	4	
1	**Site Development**					
1.1	*Main Facilities*					
a.	Enclosing Structures					
	• Enclosing dikes		A	A	A	
	• Dividers		B	A	A	B means a dike made of refuse and soil
b.	Drainage System					
	• Surrounding drains		A	A	A	
	• On-site drains (surface water)		A	A	A	
	• On-site drains (spring)		A	A	A	If necessary
	• Drains for reclaimed area		A	A	A	
c.	Access					
	• Approach roads	A	A	A	A	
	• On-site roads	A	A	A	A	
	• Others	A	A	A	A	Improvement of existing road network to access the sites
1.2	*Environmental Protection Facilities*					
	Buffer zones		A	A	A	
	Litter control facilities		B	A	A	Movable fences, etc.
	Gas removal facilities		B	A	A	
	Leachate collection facilities			A	A	
	Leachate circulation facilities			A	A	
	Seepage control facilities			B	A	
	Leachate treatment facilities				A	
1.3	*Building and accessories*					
	Site office	B	A	A	A	
	Weighbridge	A	A	A	A	
	Store			A	A	
	Safety facilities		A	A	A	Gate, fence, lights, etc.
	Fire prevention facilities		B	A	A	Water tank, extinguisher, etc.
	Monitoring facilities			A	A	Monitoring well, etc.
	Car washer			A	A	
2	**Equipment**					
	Landfill Equipment	A	A	A	A	
	Others			A	A	Water truck, inspection vehicles, etc.
3	**Operation and Maintenance**					
3.1	*Operation*					
	a. Personnel					
	b. Cover material	B	A	A	A	B means insufficient soil cover.
	c. Utility					
	• Fuel tank	A	A	A	A	
	• Water		A	A	A	
	• Electricity	B	A	A	A	
	d. Chemicals					
	• Insecticide	A	A	A	A	
	• Monitoring chemicals			A	A	
	e. Others		A	A	A	Divider, drain for reclaimed area, leachate collection pipes, etc.
3.2	*Maintenance*					
	• Main facilities		A	A	A	
	• Environmental protection facilities		A	A	A	
	• Building and accessories	A	A	A	A	
	• Equipment	A	A	A	A	

A: necessary
B: necessary under certain conditions, or may be omitted when budget is not enough

Table 8-6: Environmental Standards for Each Sanitary Landfill Development and Operation Level

Items		Sanitary Landfill Development and Operation Level			
		Level 1	Level 2	Level 3	Level 4
1	**Landfill Structure**				
1.1	Landfill Structure	Anaerobic Sanitary Landfill	Improved Anaerobic Sanitary Landfill	Semi-aerobic Sanitary Landfill	Semi-aerobic Sanitary Landfill
1.2	Achieved Condition	• Leachate generated in solid waste layers is seldom drained; an anaerobic state is maintained. Generally, the quality of leachate is poor. • Because of inactive decomposition of wastes, stabilisation is slow.	• Through gas removal facilities, the quality of leachate is slightly better than in Level 1; an anaerobic state is maintained. • The rate of decomposition is slightly improved.	• Leachate accumulated at the bottom of landfills is promptly discharged through drain pipes (leachate collection pipes). The pipes also permit natural ventilation. • This structure facilitates decomposition of solid waste because a semi-aerobic condition is maintained. The quality of leachate is much improved and generation of offensive odour is further reduced. • Water content of solid wastes is lower than Level 2	• Leachate accumulated at the bottom of landfills is promptly discharged through drain pipes (leachate collection pipes). The pipes also permit natural ventilation. • This structure facilitates decomposition of solid waste because a semi-aerobic condition is maintained. The quality of leachate is much improved and generation of offensive odour is further reduced. • Water content of solid wastes is lower than Level 2
2	**Leachate and it's Impacts on Surroundings**	•			
2.1	Leachate Generation Amount	• Leachate is freely discharged outside of both landfilling and reclaimed areas because of the absence of an enclosing structure. • Rain water flows into the landfill from catchment area and increases leachate amount.	• As for reclaimed areas, surface water is drained and discharged outside. • Rain water from the catchment area is diverted into surrounding drains. • A divider separates the area for leachate generation from the working area. • The separation of the area for leachate generation reduces leachate amount.	• As for the reclaimed areas, surface water is drained and discharged outside. • Rain water from the catchment area is diverted into surrounding drains. • A divider separates the area for leachate generation from the working area. • The separation of the area for leachate generation reduces leachate amount.	• As for the reclaimed areas, surface water is drained and discharged outside. • Rain water from the catchment area is diverted into surrounding drains. • A divider separates the area for leachate generation from the working area. • The separation of the area for leachate generation reduces leachate amount.
2.2	Leachate Control Facilities	• None	Enclosing dike and divider prevents direct discharge of leachate.	• In addition to the facilities for Level 2 are leachate cycling and monitoring facilities. • Leachate is discharged only during heavy rain from regulating pond. Leachate discharged is therefore, diluted.	• Conditions are similar to Level 3 except for effluent which is constantly treated and discharged from oxidation pond.
2.3	Leachate Treatment Facilities	• None	• None	• Retention and regulation ponds may work as oxidation pond.	• Leachate is treated in an oxidation pond with aerator.
2.4	Leachate Quality	• High leachate content, and the	• Amount of leachate is limited because of	• Amount of leachate is limited as in Level	• Amount of leachate is limited as in Level

Items		Sanitary Landfill Development and Operation Level			
		Level 1	Level 2	Level 3	Level 4
		quality is the poorest of all the landfill levels. The quality is also not expected to improve much even after a long period of time.	dike and divider. However, leachate quality does not improve even after a certain period of time.	2. • The quality of leachate improves because of the semi-aerobic condition of the landfill. • Leachate circulation facilitates waste purification • Since leachate is discharged only during heavy rain, it is therefore, diluted.	2 • The quality of leachate will be treated in order to meet the effluent standards.
2.5	Leachate Impact				
a.	Impacts on Underground water	• The degree of the impact varies depending on the permeability of bottom soil. • If bottom soil is permeable, the impacts on underground water will be immense because of high pressure head and large amount of leachate.	• The degree of the impact varies depending on the permeability of bottom soil. • The amount of leachate is much less than Level 1. However, leachate would still have immense impact if bottom soil is permeable.	• Liner is laid to protect underground water from leachate seepage. • There is very little underground water contamination	• Liner is laid to protect underground water from leachate seepage. • There is very little underground water contamination.
b.	Impacts on Surface Water	• Because leachate is freely discharged from the landfill site, the impacts on surrounding water area is very high.	• Discharge of leachate may occur when the divider is submerged and through seepage. • Although leachate amount is limited, impacts on surrounding water area is high because of uncontrolled and unimproved leachate.	• Discharge of leachate occurs only during heavy rain. • Leachate can be monitored. In case leachate to be discharged would affect the surroundings, the construction of leachate treatment facility is encouraged.	• Effluent from landfill site will satisfy the required effluent standards.
3	Others				
3.1	Vector control	• generates a large amount of flies, insects and rodents. • entices the huge gathering of crows • constant generation of rank	• Vector control is achieved and at a much improved level compared to Level 1.	• Vector control is achieved and at a much improved level compared to Level 1.	• Vector control is achieved and at a much improved level compared to Level 1.
3.2	Odours and Gas Production	• Occasional fires occur due to spontaneous ignition	• Conditions are much better than Level 1. • No fire outbreaks	• Due to semi-aerobic landfill structure, conditions are better than Level 2.	• Due to semi-aerobic landfill structure, conditions are better than Level 2.
3.3	Others	• scattering of wastes, dusty condition. • Deterioration of Landscape. • Noisy • Presence of scavengers.	• It is improved in all aspects.	• In addition to the condition achieved at Level 2, dust problems are mitigated with the use of a water sprinkler.	• Same as Level 3.

8.4.8 Maintenance of Vehicles and Equipment

The present refuse collection vehicles maintenance and repair works are carried out at the DCC Mwananyamala workshop, which is in a very poor state: not sufficiently roofed, lacking concrete floor space and the necessary machinery. Therefore, to improve the operation rate of the collection vehicles and equipment, it is very important to upgrade the conditions affecting their maintenance.

There are basically two possible alternatives for the maintenance of vehicles and equipment. The first alternative would be the allocation of preventive services to the DCC workshop and of heavy maintenance services to private shops. The second alternative would be the allocation of all maintenance and repair works to the DCC workshop.

Since preventive services are basic and essential for the maintenance of vehicles, the first alternative would be inexpensive as it would only require basic facilities and a minimum number of mechanics and workers. The private workshops must be sufficiently skilled however to properly provide DCC's fleet with the required technical services. Since some private workshops in DSM were assessed to be sufficiently skilled in these services, the first alternative could be appropriate for DSM.

The second alternative demands many skilled mechanics, a large workshop, as well as sophisticated machinery. It is capital intensive and requires a lot of money for operation and maintenance, underscoring the possibilities of technical difficulties, uncertainties and risks.

Governmental organisations tend to inefficiently conduct operations due to inflexibility, political interference, lack of motivation, slow decision-making processes, among others. Therefore, the services to be conducted by DCC should be minimised and the first alternative is concluded to be more appropriate for DSM.

8.5 Comparison of Refuse Collection and Transportation Vehicles Unit Cost

In order to facilitate the selection of optimum collection trucks, the unit waste collection and transportation costs of refuse collection trucks were estimated in this section for comparison.

Only secondary collection and transportation costs were estimated to unify the conditions for cost estimation for other vehicles.

Six different refuse collection trucks were estimated and compared in this section. The following equations were adopted to compute their productivity.

$$Tr = \frac{(60 \times t1 - t2) \times E}{60 \times (D \div V) + t3 + t4}$$

Tr: Number of trips per day (trips)
D: Travel distance per trip (km)
t1: Working hours per day (hours)
t2: Time spent daily for inspection and fuelling, etc. (min)
t3: Waste loading time (min)

t4: Waste unloading time (min)
E: Working efficiency

$$Qd = q \times d \times f \times Tr$$

Tr: Capacity of a skip container or a tipping truck (m^3)
d: Density of waste when transported (ton/m^3)
f: Working efficiency

Table 8-7: Unit Cost Comparison for Waste Collection and Transportation

Item	unit	Skip Truck			Tipper Truck			Compactor Truck
1. Unit Investment Rate								
1.1 Vehicle								
Capacity in weight	t	4	8	10	4	6	8	
Capacity in volume	m3	5	8	12	6	10	15	8
CIF Price	1000 USD	64.4	85.5	111.5	44.5	60.8	78.2	80.9
One trip distance	km	36	36	36	36	36	36	36
Velocity	km/h	40	40	40	40	40	40	40
Density	t/m3	0.39	0.39	0.39	0.39	0.39	0.39	0.585
t1: Working hour	h	7.5	7.5	7.5	7.5	7.5	7.5	7.5
t2: Daily service time	min	30	30	30	30	30	30	30
t3: Loading time per trip	min	5	5	5	60	100	150	80
t4: Unloading time per trip	min	5	5	5	10	10	10	10
E: Working efficiency of equipment		0.8	0.8	0.8	0.8	0.8	0.8	0.8
f: Working efficiency of transport		0.8	0.8	0.8	0.8	0.8	0.8	0.8
No. of trips per day	Tr	5.250	5.250	5.250	2.710	2.049	1.570	2.333
Waste carried per day	t/d	8.190	13.104	19.656	5.073	6.392	7.348	8.736
Life days	days	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Waste carried per life days	tons	14,333	22,932	34,398	8,877	11,186	12,859	15,288
Unit investment rate (1)	USD/d	4.49	3.73	3.24	5.01	5.44	6.08	5.29
1.2 Skip container								
CIF price	1000 USD	6.7	7.3	11.2	0	0	0	0
No of container per skip truck	nos	10	10	10	0	0	0	0
Total container price per skip truck	1000 USD	67	73	112	0	0	0	0
Life year	year	7	7	7	0	0	0	0
Unit container rate per day	USD/d	30.59	33.33	51.14	0	0	0	0
Unit container rate per ton	USD/t	3.74	2.54	2.60	0	0	0	0
1.3 Total Investment unit rate								
Total unit rate in USD	USD/t	8.23	6.27	5.84	5.01	5.44	6.08	5.29
Total unit rate in Tsh	Tsh/t	5,040	3,842	3,579	3,070	3,329	3,725	3,241
2. O & M cost								
Diesel consumption per hour	l/h	6.2	9.4	12	6.2	6.6	9.4	7
Diesel consumption per day	l/d	32	49	62	25	25	33	27
Diesel unit rate	Tsh/l	275	275	275	275	275	275	275
Diesel unit rate per day	Tsh/d	8,802	13,345	17,036	6,853	6,755	9,064	7,411
Labour								
driver	Tsh/d	2,333	2,333	2,333	2,333	2,333	2,333	2,333
worker (5 per tipper truck)	Tsh/d	-	-	-	7,778	7,778	7,778	7,778
Maintenance & Repair (20% of basic price)	Tsh/d	4,508	5,985	7,805	3,115	4,256	5,474	5,663
Total O & M cost	Tsh/d	15,643	21,663	27,175	20,079	21,122	24,650	23,185
O & M unit rate	Tsh/t	1,910	1,653	1,383	3,958	3,304	3,355	2,654
3. Total Unit Rate								
Total unit rate	Tsh/t	6,950	5,495	4,962	7,029	6,633	7,079	5,895

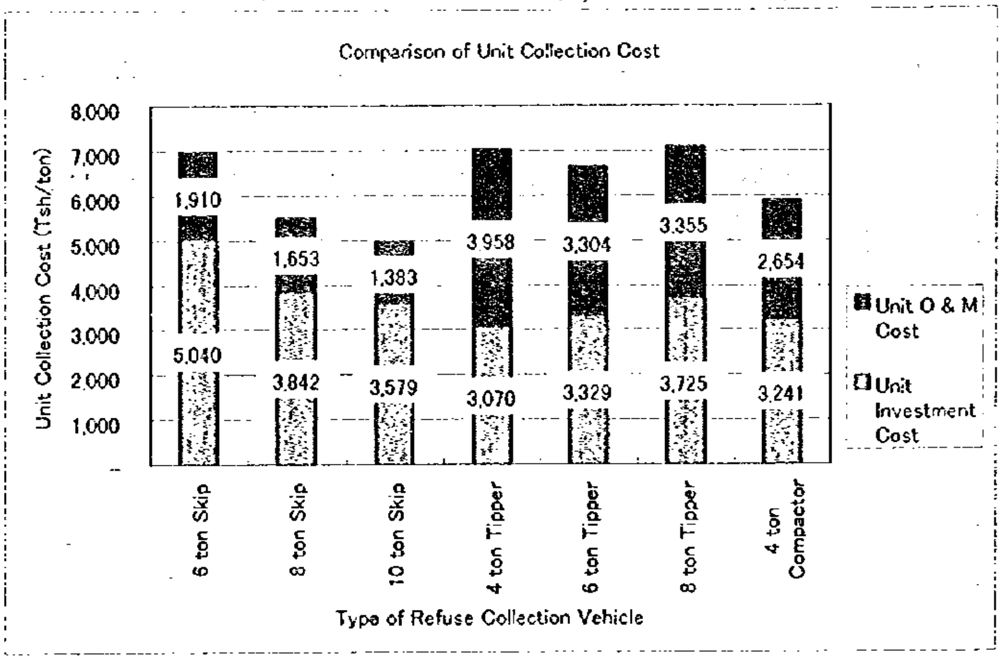


Figure 8-4: Comparison of Collection Cost by Vehicles

The estimated unit cost of a 10 ton skip truck is cheapest among these six vehicles. However, 10 ton skip truck is not recommended for DSM because of the following reasons.

- It has three axles which associates with maintenance difficulties.
- 10 tons skip trucks are too big for roads in DSM.

8.6 Selection of An Optimum Technical System

Following the examination of SWM technical sub-systems, the selection of an optimum SWM technical system for DSM was proposed.

Table 8-8: An Optimum MSW Technical System for DSM

System	Proposal
Discharge and Storage	• Source separation: Separate recyclable and non recyclable wastes • Type of storage: Plastic sack Public skip container • Collection frequency: More than twice a week • Collection method: Mixed collection for non-recyclable wastes • Type of collection: UA: Curb side collection SUPA: Curb side collection and Point collection SUUA: Curb side collection and Point collection RA: Point collection • Collection time: Day collection for most areas, and night and early morning collection for the city centre • Type of collection vehicle: UA: 4 ton compactor truck (6 ton tipper truck by 2002) SUPA: 6 ton tipper truck and 8 ton skip truck SUUA: 6 ton tipper truck and 8 ton skip truck RA: 8 ton skip truck • Transportation system: Direct transport by motor vehicle
Primary Collection	• Handcart collection is generally appropriate for most areas in DSM which require primary collection.
Secondary Collection and Transportation System	• UA: 4 ton compactor truck (6 ton tipper truck by 2002) • SUPA: 6 ton tipper truck and 8 ton skip trucks • SUUA: 6 ton tipper truck and 8 ton skip trucks • RA: 8 ton skip truck
Street Sweeping	• Manual sweeping method
Intermediate Treatment	• Only on-site composting is encouraged.
Recycling	• Recycling activities are encouraged through institutional and educational programmes as long as collection does not involve any cost.
Final Disposal	• Each district with a sanitary landfill for the disposal of its own waste. • Sanitary landfill (either Level 2 or 3) is adopted.