

CHAPTER THREE

Techniques Used in the Composting Process and Quality of Compost

3.1 Composting Process

Composting refers to the controlled decomposition of organic matter by aerobic microorganisms into stable humus like material. The composting process is managed with the aim of accelerating the decomposition, optimizing efficiency and minimizing any potential environmental and health issues that could develop. As illustrated in Figure 3.1, during the composting process, compostable material or feedstock undergoes a series of biological conversion processes while producing carbon dioxide, heat and water as by-products. The usable end product of composting is the compost, which is dark in color, peat like, has a crumbly texture and an earthy odor, and resembles organic top soil. A good composting process eliminates most of common weed seeds and organisms that may be pathogenic to humans, animals or plants.

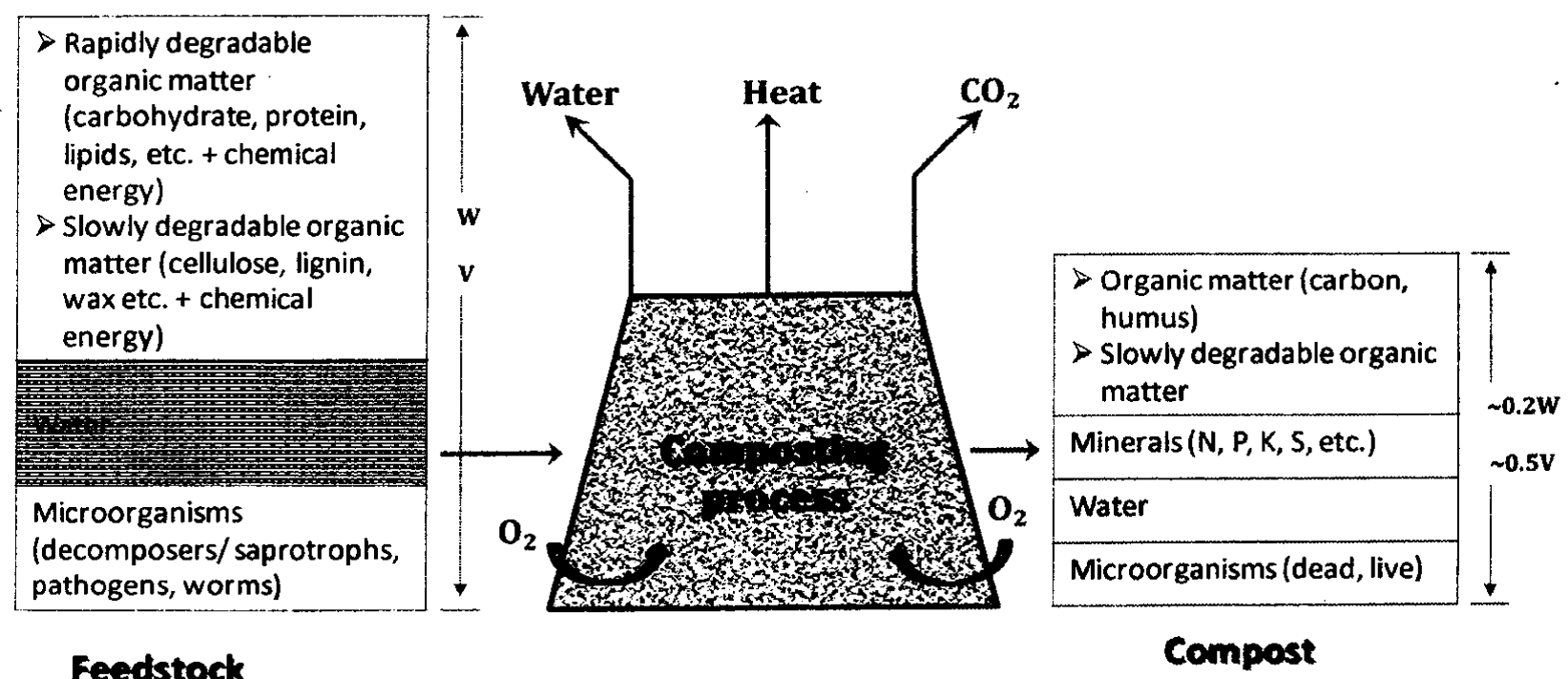


Figure 3.1: The Composting Process

Composting of organic fraction of municipal solid waste (MSW) can significantly reduce waste stream volume and has environmental and economic advantages. Thus, the National Solid Waste Management Policy (2007) has recognized composting of biodegradable materials in municipal waste as a MSW pre-treatment option when the cost of final disposal and other MSW treatment options are high. The policy further highlighted that household composting and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no municipal management or transportation. Thus, within a concept of waste recovery, the source

separation and on-site composting of organic fraction of MSW can resolve some of the major economic issues faced by local authorities along with the environmental and social issues associated with disposal facilities. However, the performance of home compost makers and the quality of the compost products are issues to be further addressed for the successful implementation of on-site composting.

There are various technologies used in Sri Lanka for aerobic pre-treating of MSW prior to material and energy recovery and subsequent final disposal in landfills. In situ and centralized aerobic composting techniques are commonly used as a means of organic material recycling process in which the end products are recycled back to the environment through land application as a fertilizer or soil amendment. There are a number of in situ composting methods available in Sri Lanka (Annex 1). However, in this research, we have focused mainly on centralized type of aerobic composting which is widely used in MSW composting.

3.2 Centralized Composting of MSW in Sri Lanka

Until very recent past, municipal solid waste management delivery had traditionally been viewed as the collection and disposal of waste and it has been considered unsustainable. While collection would help remove waste from generators, collected waste is often disposed at open dumps without much concern for environmental pollution and implications on human health. Lack of suitable and adequate lands for safe disposal of MSW has been one of the major problems affecting urban areas, due to high population densities, resulting in haphazard and indiscriminate dumping of large quantities of MSW.

Due to the importance and gravity of the MSW issue, there have been several national and international support programs to uplift the SWM sector in the country. The first national level project; study on MSWM in secondary cities in Sri Lanka which was funded by Japan International Cooperation Agency (JICA), started in 2002 and continued for two years. By this project institutional capacities of seven local authorities (Kandy, Gampaha, Matale, Nuwara Eliya, Baddulla, Negambo MCS and the Chilaw UC) were strengthened. Secondly, as per the recommendation of the project, the National Solid Waste Management Support Center (NSWMSC) was established in 2007 as an affiliated institute of the Ministry of Provincial Councils and Local Government. The NSWMSC facilitates local authorities with technical support for development of all segments in SWM, and coordinates with government and non-governmental organizations to secure financial assistance for local authorities to upgrade SWM services. The financial support from JICA for NSWMSC has been reduced, and NSWMSC is now functioning as a government organization funded by the Ministry of Local Government and Provincial Councils.

At the same time, the Ministry of Environment and Natural Resources has launched a national level program in the name of PILISARU under the Chairmanship of the Ministry of Environment and Central Environmental Authority in participation with other government organizations, private institutions, NGOs and various

technological specialists. The main aim of the PILISARU project was to solve MSW problem in 5 years starting from 2008. The PILISARU program was funded by the central government budget allocations up to Rs 5.675 billion for the first three years. The PILISARU program has funded hundreds of small, medium and large scale MSW management facilities such as treatment of organic waste by centralized composting, source segregation and resource recovery, and promoting recycling.

Another notable initiative is the Ampara Environmental Remediation Program (2006-2011) which was funded by the European Union (EU). The project implementing agency, the United Nations Office for Project Services (UNOPS) implemented several MSW improvement projects in the Eastern Province and the projected total expenditure is US \$12.3 million. In addition, several non-governmental and international donor agencies work on the MSWM field on different scales.

Consequently, there has been a paradigm shift in the way that waste management is perceived. The emphasis is now on waste minimization and reduction at source, recovery of resources prior to disposal, and promoting recycling of waste materials with the ultimate goal being a national sustainable solid waste program.

Composting of municipal solid wastes in centralized facilities is becoming popular, in the frame of integrated municipal solid waste management and, in particular in the diversion of biodegradables from dumping/landfilling. The objective of MSW composting can be approached in two main ways:

1. The solid waste management approach, wherein composting is a way of treating organic waste within an integrated solid waste management system. Compost is seen as a by-product.
2. The marketing approach, wherein composting is a way of producing a valuable product that can be sold. Composting is the core of all activities.

With the initiative and incentives through the PILISARU program launched by the Ministry of Environment in 2007, there was a boost in setting up of centralized MSW composting facilities in the country. At the launch of the PILISARU program, the major aim of centralized MSW composting was focused on the first objective, wherein public health and environmental conservation were of greater importance. The capital expenditure for setting up composting facilities were drawn either from public funds through PILISARU or foreign/local donors. In addition, the local authorities were facilitated with adequate human resource training and awareness programs. However, with the later developments, local authorities opted to focus more on centralized composting as a business that can partially recover MSW service expenditure through compost sale (Perera et al., 2010).

The following section summarizes the technologies used in centralized composting of MSW in Sri Lanka, with special emphasis on the use of engineering principles and management strategies.

3.3 Techniques used in Centralized MSW Composting

Pre-processing

Pre-processing is typically performed by three actions; 1) sorting MSW and removing materials that are difficult or impossible to compost; 2) reducing the particle size of the feedstock material; and 3) treating feedstock to optimize composting conditions. The first aspect of the pre-processing, MSW sorting in Sri Lanka is generally practiced at three levels; 1) sorting at point of generation; 2) segregation at the collection by collection workers; and 3) manual sorting at a centralized facility. Among the pre-processing activities, however, only the manual sorting at the centralized facility is widely practiced in Sri Lanka which has to be changed to source separation for better quality compost production (Table 3.1). Generally mixed/comingled MSW requires extensive sorting and separation, which is generally done by manual labor. The degree of sorting depends on several factors, including the source of the MSW (residential, commercial, street sweepings etc.), quality of the final product, and the operations and technology involved.

Table 3.1: Advantages and Disadvantages of Source Separation Versus Commingling MSW

Source-separated materials	Mixed(commingled) waste
<p>Advantages:</p> <ul style="list-style-type: none"> ✓ Less chance of contamination results in higher quality compost. ✓ Less money and time spent on handling and separation of material at the site. ✓ Provide an educational benefit to residents and might encourage waste reduction. 	<p>Advantages:</p> <ul style="list-style-type: none"> ✓ Usually collect with available equipments and workforce. ✓ Convenient for residents because no separation is required.
<p>Disadvantages:</p> <ul style="list-style-type: none"> ✓ Can be less convenient to residents. ✓ Might require the purchase of new equipment/machinery/vehicles and containers. ✓ Might require additional workforce for collection. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> ✓ Higher potential for contamination, which can result in lower-quality compost ✓ Higher processing and facility fee

Compost processing in Sri Lanka

At the local authority's level, composting practices range from simple open air static-pile composting to large-scale mechanized facilities. Figure 3.3 provides a brief overview of different composting techniques, and windrow composting is the most widely adapted method across the country.

Indoor composting in turned windrows is a common technique widely adopted for mixed MSW and garden waste. Although outdoor windrow systems are being used in some facilities, the system is less suitable for more problematic wastes such as food wastes, organic rich MSW or wastes very rich in perishables because of higher risk of odor, attraction of animals and hygienic reasons. The more damped MSW is being mixed with mature feedstock or dry garden waste, and generally protected under a roof to prevent excessive leachate generation. Static piles with forced aeration systems are not common in Sri Lanka; instead few LAs use passively aerated systems that were developed by the solid Waste Management Research Unit of the University of Peradeniya (Basnayake *et. al*, 2008).

Composting facilities are designed similar to industries where raw materials are being processed into final products. An engineered composting facility helps in smooth operational and post processing activities aiming a high level of efficiency. As illustrated in Figure 3.2, most of the centralized composting facilities are equipped with adequate facilities and machinery for composting, but generally have limited facilities for handling of rejects/waste.

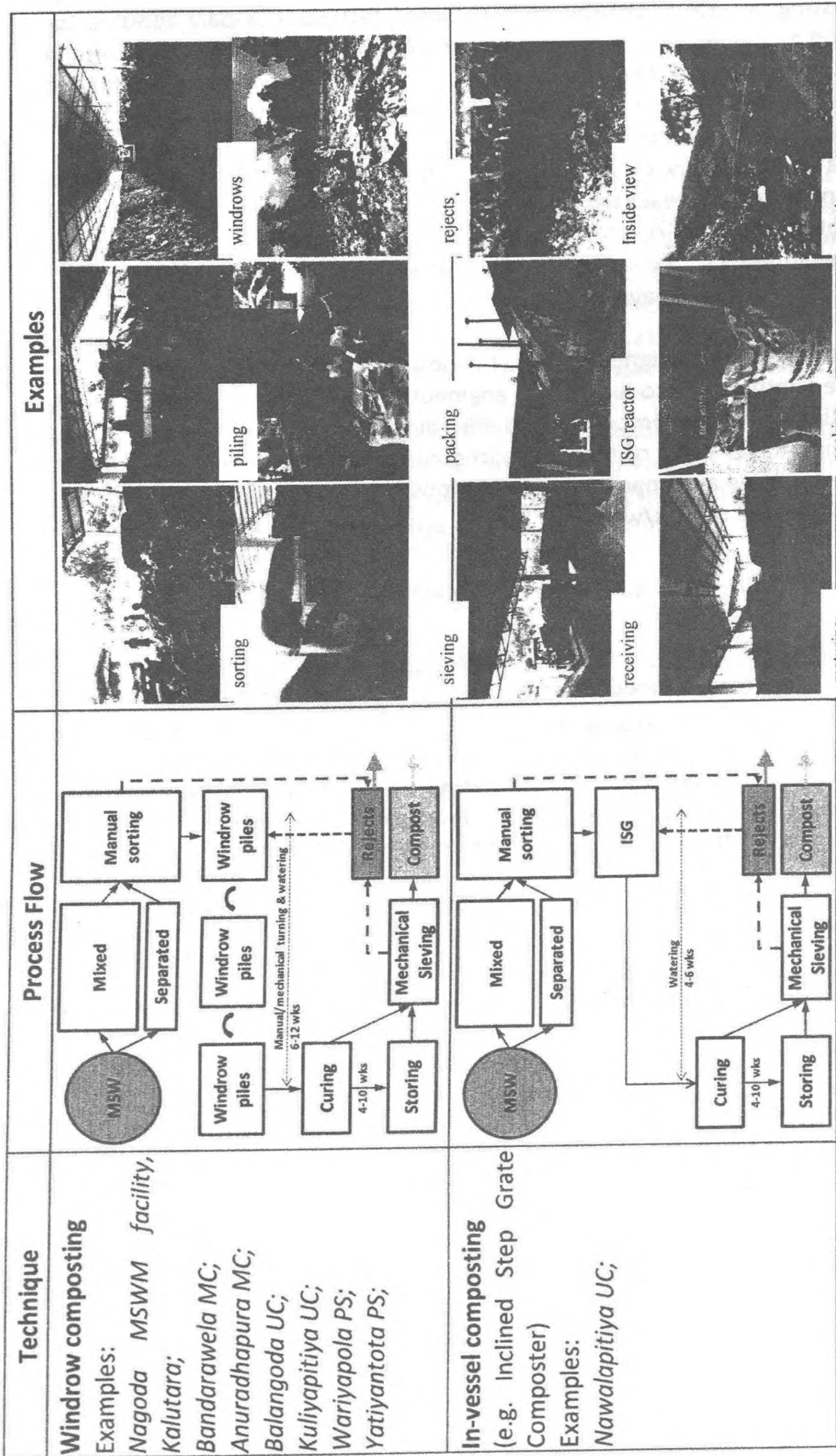


Figure 3.2: Common Methods of Centralized Composting of MSW

Except in few facilities, managers or supervisors have limited skills to operate and manage the composting facilities. Table 3.2 summarizes some of the key parameters that should be considered in compost manufacturing for market.

Table 3.2: Factors Influencing the Composting Process and Quality of Final Product

Aspect	Preferred condition	Remarks
MSW characteristics	Organic fraction of MSW	Kitchen waste, food waste, garden waste, paper and small amounts of non-degradable/ long-term degradable materials may be present
Particle size	25-75 mm for optimum results	Smaller particles increase the density thus reduce the air movement inside the pile, larger particles takes a long time to disintegrate and decompose
C:N ratio	25 to 50	C:N ratio above the limit prolong the decomposition and very low C:N ratio of feedstock may impend anaerobic condition and ammonia leaching
Blending & seeding	1-5 %	Addition of partly decomposed matter accelerate the decomposition at early stages, especially when the feedstock is garden waste
Moisture content	55% (optimum)	Higher moisture increases leachate generation and reduces aeration, dryness ceases the decomposition
Windrow size	2 m width and 1.5 m height and 3 m long	Wide and tall windrows restrict the air movement inside the pile
Mixing/turning	4-5 days (optimum) Weekly (recommended)	Low turning frequency reduces the aeration, mixing and disintegration and slower the decomposition
Maturing/curing	Weekly mixing/turning (optimum)	Continue pile mixing/turning until temperature drops to 40 °C or less, and add water while mixing/turning
Monitoring parameters		
Temperature	50-55 °C for first few days 55-65 °C for reminder period	Temperature below 50 °C during the composting caused by low C:N ratio, excessive moisture, dryness, compaction due to large pile size, toxins
pH	7 – 7.5 (optimum)	Not above 8.5 to minimize nitrogen losses via ammonia volatilization, very low pH at early stages indicates excessive, fast decomposable carbohydrates in feedstock
Maturity indices		
Stability	<i>Simple tests</i> <ul style="list-style-type: none"> • C:N ratio <25 • Self heating test <i>Advance tests</i> <ul style="list-style-type: none"> • Specific O₂ uptake rate • CO₂ evolution 	Simple tests are cheap and easy but are low in accuracy Advanced tests are more accurate but require special equipment and skills to perform
Toxicity assessment (Phytotoxicity)	NH ₄ -N:NO ₃ -N ratio, Compost bioassays	Caused by the presence of organic chemicals such as lactic and acetic acid, herbicides, heavy metals, and pathogens

Source: U.S. Composting Council (2002).

3.4 Overview of Compost Processing Technologies

In any technology, processing methods should be chosen to maximize the speed of the composting process and to minimize negative effects, such as fly breeding, odor release and leachate runoff. The level of effort required for processing composting feedstock depends on the nature of the feedstock, the desired speed of production, the requirements for worm control, odor and leachate control, and the quality requirements for the finished compost. A facility's financial resources and available space are also important. Greater the speed of the process, the more odor and leachate control is necessary. In general, more resources and higher levels of effort are necessary to compost a MSW feedstock than a garden waste/trimming feedstock, largely because of the diverse nature of MSW. Compost processing occurs in two major phases: the composting phase and the curing phase;

- 1) Composting phase: Microorganisms decompose the readily available organics/nutrients present in the feedstock and most of the actual change in the feedstock occurs during this stage. Consequently, the most intensive degradation and change of phase of decomposition tend to occur here.
- 2) Curing phase: Once the rapid composting phase ends, the compost should be cured. Curing should take place once the materials are adequately stable. Testing for stability is an inexact science but oxygen uptake and CO₂ evolution tests can be considered to determine the degree of maturity of compost derived from MSW feedstock. A simple method of stabilization is monitoring the internal temperature of the compost pile once it is turned. If reheating of the pile occurs, then the material is not stabilized. Another method is to put the compost material in a plastic bag for 24 to 48 hours at optimum moisture level of 55%. If foul odors are released when the bag is opened, the materials are not ready for marketing. Reason for most of the negative feedbacks on MSW compost is due to marketing of immature composts and not due to containing heavy metals and toxic organics.

In Sri Lanka, many composting facilities use a concrete pad to collect and control any leachate that is produced during the first stages of composting. The most common way to handle leachate is to collect the leachate, dilute with water and reintroduce into the compost pile (e.g. Balangoda Composting Facility). However, this should not be done once the composting materials have passed the high-temperature phase (e.g. after 10 weeks of windrow composting), because harmful microorganisms can be reintroduced with the leachate.

3.5 Compost Manufacturing and Quality Control

In Sri Lanka, most composting facilities that process MSW feedstocks are designed and operated primarily to reduce the waste volume prior to final disposal. However, the viability of composting facility as a sustainable solution in MSW management hierarchy depends mainly on cost and benefit of composting, consequently the

quality of marketable product. Therefore, it is crucial for LAs to change their main objectives from landfill diversion to product manufacturing, if a sustainable composting facility is to be established.

The use of the composted organic fraction of MSW as soil amendment may be a method of improving the low organic matter (OM) content of many cultivated soils in Sri Lanka, particularly in the areas where soil OM has gradually decreased over recent years and there is a chronic deficiency of soil OM. Compost intended for use as a growing method should meet more stringent quality criteria in comparison with compost used in reclamation of marginal and degraded soils or in other special uses such as landfill cover. The most important characteristics of MSW composts that may affect their use as a growing media/soil amendment are derived from their physical properties (air and water supply), and their chemical properties (pH, electrical conductivity and nutrient content) and also from the absence of toxic compounds, including heavy metals, hazardous organic compounds and pathogens. Accordingly, a good quality control procedure is necessary before the compost can become a recommended soil amendment for agriculture.

In order to market MSW compost successfully to many end users, concerns about potential threats to soil, plants, livestock, and humans must be addressed. One of the primary concerns of local consumers is the low nutrient value, presence of heavy metals and toxic organic compounds in MSW compost. At the market, the compost should be of a consistent quality, especially to customers who expect a certain quality product. This may not be as important to the one-time buyer. However, if the quality of the compost is good, the one-time buyer could become a regular customer. In addition, if some compost varieties are extremely poor in quality, customers' confidence in all composts may be reduced. Quality assurance (e.g. SLS standards) for consistent production of high-quality compost is a necessity for compost marketing.

This section primarily focuses on factors that affect the quality of compost and techniques that can be applied to improve the quality.

Factors Affecting the Compost Quality

The best method to obtain a quality feedstock from MSW for composting is to collect the compostable waste separately from the point of generation. For this, MSW point source separation has to be improved (Jagath *et. al*, 2002). In case public cooperation and law enforcement are not effective, waste sorting at centralized facility can be practiced. However, the quality of feedstock may be inferior to the source separated waste.

Changes in the compost feedstock also change the compost quality; feedstock material should be carefully controlled to ensure consistent compost quality. This may mean that some non-compostable materials should be rejected at the compost site if the product from these materials will be difficult or impossible to market. If accepted, attempts should be made to segregate these feedstocks and market the

resulting compost separately. The following paragraphs mention some of the substances which have greater potential to be in compost, if adequate measures are not applied in feedstock selection, sorting, processing and final finishing.

Potential Toxic Biological Agents

Potential health and safety concerns at composting facilities include exposure to bioaerosols, potential toxic chemicals, and other substances. Bioaerosols are suspensions of particles in the air consisting partially or wholly of microorganisms (Gerba, 1995). The bioaerosols of concern during composting includes actinomycetes, bacteria, viruses, molds, and fungi. For instance, *Aspergillus fumigatus* in decaying organic matter can be inhaled or can enter the body through cuts and abrasions in the skin (Tontti *et. al*, 2011). In susceptible individuals, however, it can inhabit the lungs and produce fungal infections. Another health concern at composting facilities is exposure to endotoxins. Endotoxins are toxins produced within a microorganism and released upon destruction of the cell in which it is produced. Because bioaerosols and endotoxins are both carried as dust, dust control measures should be incorporated into the design and operation, and final product processing of the facility. These substances may be present in small quantities in the finished product therefore proper guidance should be given for safe handling during application.

Potentially Toxic Chemicals

Some volatile organic compounds (VOCs), such as benzene, chloroform, and trichloroethylene present in mix MSW can pose risks to workers at MSW composting facilities (Gillett, 1992). Certain solvents, organic acids, paints, petroleum products and residues, and cleaners contain VOCs. The combination of periodic turning of windrow systems and elevated temperatures can drive VOCs from the composting material into the surrounding atmosphere. Workers are more likely than compost users to be exposed to VOCs, because most of the VOCs in the feedstock volatilize from composting piles within the early few days. To avoid worker exposure to VOCs in enclosed spaces, adequate ventilation is required in composting facilities. Although, control technologies developed for odor control may be applied to VOC control, the best method of controlling VOC emissions is to limit their presence in the feedstock.

Heavy metals

Out of all hazardous/toxic substances that may be present in MSW compost, heavy metals have been the focus of most attention. Contamination of MSW compost by heavy metals can cause harm to public health and environment and is the major concern leading to its restricted agricultural use in some countries. Mixed waste composting is therefore not an option for sustainable waste management, but this issue has not been taken seriously by some of composting manufacturers. Although composting of mixed waste may lead to production of compost contaminated by heavy metals, the general perception is that the composting of source separated

organic waste may not contain elevated levels of heavy metals. For instance, the following table shows the compost quality of eleven MSW compost samples analyzed for different parameters (Karunaratna *et. al*, 2013).

Table 3.3: Quality Parameters of Eleven MSW Compost Samples Randomly Picked from Composting Facilities in Sri Lanka (Karunaratna *et. al*, 2013); Heavy Metal Quantities are in ppm.

Parameter	Sample code											max	min	Ave
	a	b	c	d	e	f	g	h	i	j	k			
pH (1:1)	8.1	7.3	8.9	8.6	8.3	8.3	8.9	8.0	8.2	8.1	7.9	8.9	6.9	8.1
EC (dS/m) (1:5)	4.1	6.7	8.1	8.9	1.6	2.1	8.5	7.3	6.5	5.9	5.3	8.9	1.3	5.1
Moisture (%)	17.0	7.6	23.0	26.0	34.0	41.0	11.0	27.0	30.0	26.0	31.0	41.0	7.6	27.2
Organic Carbon (%)	22.6	31.3	41.7	32.4	29.9	32.1	44.3	42.1	28.1	32.7	25.1	44.3	21.9	31.8
Total N (%)	1.0	0.1	1.0	1.6	1.0	1.0	1.0	0.9	1.8	1.6	1.5	1.8	0.1	1.1
Total P -P ₂ O ₅ (%)	0.9	0.0	1.1	1.4	0.7	0.8	1.0	1.0	1.1	1.3	1.0	1.4	0.0	0.9
Total K - K ₂ O (%)	1.5	1.3	2.2	2.3	0.5	1.6	2.0	1.7	1.7	1.7	1.5	2.3	0.5	1.5
Carbon: Nitrogen (C/N)	23.4	36.3	41.1	20.2	30.9	33.2	44.5	46.0	18.0	20.6	16.2	46.0	16.2	29.2
Cadmium (Cd)							15							
Chromium (Cr)							185							
Copper (Cu)							80							
Lead (Pb)							130							
Mercury (Hg)							1							
Nickel (Ni)							30							
Zink (Zn)							190							

Source: Karunaratna *et. al*, 2013

The content, behavior and significance of heavy metals in composted waste materials is important from two potentially conflicting aspects of environmental legislation in terms of: (a) defining end-of-waste criteria and increasing recycling of composted residuals on land and (b) protecting soil quality by preventing

contamination. Thus compost quality guidelines should consider the effects of heavy metals in compost and amended soil as a basis for achieving a practical and sustainable balance between these different policy objectives, with particular emphasis on agricultural application.

Generally, all types of municipal solid waste (MSW) compost contain more heavy metals than the background concentrations present in soil and will increase their contents in amended soil. Total concentrations of heavy metals in source-segregated and garden waste/ yard trimming compost are typically below standard limits for agricultural use and below risk-based thresholds that affect human health. Moreover, there is general consensus in the scientific literature that aerobic composting processes increase the complexation of heavy metals in organic waste residuals. Metals get strongly bound to the compost matrix and organic matter, limiting their solubility and potential bioavailability in soil. Lead is the most strongly bound element and Ni the weakest, with Zn, Cu and Cd showing intermediate absorption characteristics. The availability in soil depends on the nature of the chemical association between a metal with the organic residual and soil matrix, the pH value of the soil, the concentration of the element in the compost and the soil, and the ability of the plant to regulate the uptake of a particular element. Therefore, bad effects on the environment, human health, crop quality and yield, and soil fertility, from heavy metals in source-segregated MSW or garden waste/ yard trimming compost are minimal.

3.6 Technical Constraints of Composting Municipal Solid Waste in Sri Lanka

This section highlights few technical constraints faced by centralized composting facilities in Sri Lanka.

The most common technical issue is the receiving of mixed and unsorted MSW at the centralized composting facility. The mixed waste is often contaminated with household hazardous compounds and materials such as batteries, small electronic appliances, and discarded electrical bulbs, discarded pharmaceuticals and chemical waste from small industries. The manual sorting can only separate apparently visible and proportionally large hazardous particles from the mixed MSW, leaving the small hazardous materials to mix with bulk feedstock. It has been observed that the contamination with household hazardous waste is a major source of heavy metal found in compost. The issue can only be solved, if very strict regulations and monitoring mechanisms are established to prevent co-disposal of hazardous and non-hazardous solid waste at household and commercial (trade) sector. Separation of hazardous waste at the centralized facility requires special machinery and instruments which are not appropriate for small and medium scale composting facilities.

Generally, the mixed MSW and biodegradable waste collected by LAs has the water content far above the optimum amount of moisture required for composting. The high moisture in the composting feedstock and endogenic moisture generated from

rapid degradation at the initial phase of decomposition generate excessive amounts of leachate that cannot be disposed by recirculation. Thus, the management of excessive leachate produced in early stages of composting, especially in commonly practiced windrow composting, has become the major issue faced by compost facility management. The issue is very common in the wet zone of the country where rain occurs for at least half of the year. Thus, investments on additional leachate storage and treatment facilities are essential to overcome the condition.

Disposal of pre-rejects and post-rejects from composting process is another problem faced by most of the centralized composting facilities. Recent research revealed that the portion of rejects in the form of non-recyclable plastics and inert can be 40 to 50% of incoming MSW weight. If the composting facility has not been established as part of integrated MSW management strategy, often such rejects are stockpiled in and around the composting facility. The storing of rejects usually occupies the space required for proper compost facility management.

Composting feedstock shall undergo thermophilic (temperature between 65 and 75 °C) stage at least for a week to destroy pathogen and weed seeds present in the MSW. However, composting piles smaller than 1.5 m in height and width often cannot reach high temperatures and thermophilic state may not be maintained for a considerable time period. This problem can be avoided by constructing larger windrow piles using the waste collected for several days when the daily receiving amount is less than two tonnes.

The national survey on MSW in Sri Lanka revealed that most of windrow composting facilities have not been designed with adequate expertise consultation. The common practice is to replicate the system established in other LAs; however, site specific conditions and operational procedures are often missed out in the designing process. This has ultimately lead to malfunctioning of facilities and producing inferior quality compost at the end.