Opportunities for sustainable municipal solid waste management services in Batticaloa: Business strategies for improved resource recovery

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Contributing Authors:

Dr. Miriam Otoo
Dr. Sudarshana Fernando
Ms. Nilanthi Jayathilake
Mr. Mohamed Aheeyar
Ms. Ganesha Madurangi

Affiliation: International Water Management Institute, Colombo, Sri Lanka.

Correspondence to Dr. Miriam Otoo: E-mail: m.otoo@cgiar.org

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Executive Summary

The objective of this research project was to recommend strategies for the recovery and productive reuse of municipal solid waste (MSW) of four compost plants (Batticaloa Municipal Council – BMC plant; Kattankudy Urban Council – KUC plant; Mamunai Pattu Pradeshiya Sabha – MPPS plant; and Manmunai South and Eruvi Pattu – MSEP plant) in the Batticaloa district, with a view of ensuring the provision of sustainable waste management services by the respective local authorities (LAs). The 4 compost plants generate significant benefits to communities by reducing health hazards from decreased exposure to untreated waste. However, similar to many cases in other developing countries, they receive significant external financial support to sustain their operational activities. It is imperative that, although the initiatives have a strong social element, they reinvent their operational mechanisms from a business perspective to ensure long-term sustainability. In that regard, we define long-term sustainability for the compost plants as been financially self-sustaining (at least able to reach total cost-recovery). It is important to note that while financial viability is essential, long-term sustainability is determined by a myriad number of factors to include a sound marketing strategy, efficient operational system, amongst others; and which are considered here.

The research aimed to provide a set of recommendations/ strategies for adoption by the LAs. The research included an economic (business and market), and technical analysis to understand the existing (and support further) operational (technical and business) strategies used by the LAs for municipal solid waste management[1]. The recommendations are based on the assessment of the sub-optimalities in the operational systems of the compost plants. This represents important information for the LAs (waste management regulators/ service providers), who are constantly exploring a holistic approach in generating multiple benefits from waste reuse businesses. In this regard, key recommendations to improve the long-term sustainability of the compost plants include:

a) **Strategic level recommendations –** focuses on the broader business architecture of the plants.

Currently the four compost plants in Batticaloa operate under four different local authorities. The individual local authorities oversee the operations of the four compost plants and have the autonomy in decision-making on all resource allocations for the compost plants (finance, manpower, technology, etc.), which means that each plant operates as a Strategic Business Units (SBU). Each SBU has its own autonomy and decision making capacity, but is still mandated to report to a higher-level authority. Whilst currently, the role of the higher-level authority is played by the ACLG/ CLG office; an additional suggested body can be an elected/selected corporate entity/committee which consists of business-level nominees of four local authorities and at least one member each from the ADCs and Department of Agriculture, to create balanced ownership and involved of these relevant stakeholders for the project. This essentially creates an avenue for nonaligned entities to support the compost plants in achieving their intended business outcomes.

b) **Business level recommendations** – focuses on the technical optimalities of the compost production process along the entire value chain from waste (input) procurement to product finalization; and market and financial-related factors (e.g. market demand, marketing and pricing strategies, cost-recovery potential.

[1] For the purpose of this research project, waste management refers to the specific component of the value chain that focused on resource recovery from municipal solid waste (i.e. nutrient recovery from MSW composting).

From a technical perspective, the ff. recommended adaptations to the operational system are required:

- It was observed that the input material and low supply of food and short-term biodegradable waste evidence low degree of separation at sources such as institutes, hotels, and households. The challenge of poor waste input quality invariably affects the quality of the compost product as noted with the high sand content, low nutrient levels, high inert material content of the compost product. In the short-term and absence of enforceable measures for waste segregation, the compost plants can consider the following two approaches to address this challenge: (a) identify high nutrient waste sources such as livestock waste (manure), fecal sludge, etc., and increase quantities of short-term degradable high N nutrient waste collected and used in production process; and (b) implement polluter-pays policy for institutions (restaurants, hotels) to reduce quantities of unsegregated waste received, or least reduce related operational costs incurred. In order to obtain sustainable waste segregation practices, community awareness and regulatory interventions are additionally needed.
- According to the analyses, it was observed that the dimensions of the compost piles were practically difficult to manage and the surface area to volume ratio (SA/V) of compost piles significantly exceeded 1 reducing process efficiency. Given the hot weather conditions in the Batticaloa region, it is recommended that the pile sizes are kept at minimum required levels (windrow height to 1 - 1.5 m[2]) to maintain optimum conditions for composting. Large heaps can result in an anaerobic process within the windrows due to low aeration, which may cause foul smells and prolonged process time and reduced sanitization of the final product.
- Experiences from other compost projects in Sri Lanka reveal that open windrows during the initial stage (approximately 3-4 weeks during the thermophilic phase) is successful, however, after the initial stage, windrows need to be moved to covered areas to ensure an effective process. This is a requirement in the case for all the compost plants, especially given the heavy rainfall in Batticaloa, which can raise the moisture content higher than the optimum, leading to a low oxygen environment (i.e. anaerobic environment).
- The design capacities and operating levels of each compost plant compared to the design capacities showed relatively low performance of the plants. Consideration of alternative waste streams such as fecal sludge for the production of a co-compost product[3] represent an opportunity to improve production efficiency, the nutrient quality of the compost product (refer to Annex 1 and 2) and market demand.
- Additionally, it is imperative that the compost plants conduct regular quality testing to assure the officers of the quality of the BEST-Comp product. This will incentivize them to promote the product to farmers. Product certification and on-field trials in direct collaboration with farmers (free compost product trials) represents an added-value to increasing adoption.

From a market perspective, the ff. recommended adaptations to the operational system are required:

- Price was noted as a significant factor influencing farmers' purchasing decision of Best-Comp (compost product). Farmers noted that the current price of compost (Rs. 8/kg – wholesale price; Rs. 12/kg – retail price) was higher than they would like to pay and preferred to pay Rs.6 -7 per kg. This suggests that a good strategy would be to implement a penetrative pricing strategy (a lower market

[2] Windrow dimensions should be more or less 1 m in height and 1 m in width given the climatic conditions in Batticaloa.

[3] Fortifer, a nitrate fortified and pelletized, faecal sludge and MSW co-compost; which addresses the current challenges associated with using 'regular' compost or even dried faecal sludge, perceived to be bulky, low nutrient content, related health risks from product.

price than the prevailing competitive market price) to increase adoption rates. Compost plants can benefit from economies of scale from increased production, permitting a reduction in compost price.

- Best-Comp faces some strong competition from large-scale compost producers, like ARAFA, CMP and livestock waste-based compost producers. In addition to implementing a penetrative pricing strategy to increase adoption rates, strong awareness programs coupled with promotional initiatives such as testing with free samples will also be important to further increase market demand. The compost plants can create pilot projects in the localities to demonstrate the effect of BEST-Comp compost on different crops to convince farmers of product quality.
- Compost product differentiation for different crops via regular customer testing and evaluation to tailor product features such as nutrient content levels, packaging and branding to specific consumer preferences can significantly increase market demand and invariably revenue generation.
- A high reliance on the ADCs puts the compost plants at a risk especially in view of the fact that the ADCs also promote other compost brands (private sector) which are clear competitors. Strategic partnerships with private entity distributors is imperative. An additional consideration is the creation and promotion of a hotline number for compost orders and feedback from farmers, which has additional benefits of: a) creating a direct link between the compost plants and the farmers; b) informing the production of the plant to adequately meet market demand.
- Repositioning of the BEST-Comp product by increasing the brand awareness via an SLS certification can significantly add-value to the product as it is an indicator of product quality valued by farmers and agricultural extension agents who promote them.

From a financial perspective, the ff. recommended adaptations to the operational system in required:

- Improvements in plant performance to reach break-even point require a 90% operation efficiency level and excluding depreciation, for all the plants with the exception of the MPPS plant which still recorded a loss of Rs. 1.46 million/annum. Increased operational efficiency is achievable given easy accessibility and availability of the waste resource input. Increased production can create economies of scale benefits and reduce product price, invariably increasing market share. The financial sustainability of the MPPS plant is highly questionable as the plant needs to operate at a very high level of operating level i.e. 141% of design capacity in order reach the break-even point where the current operating level is only at 16%. Using the annualized cost on observed data[4], however, an improvement in the profit levels was observed for all the compost plants under increasing efficiency levels. This result is particularly important for the MPPS plant which posted negative profit levels even under 90% efficiency. This is because although a high volatility in the monthly costs was recorded for the other plants, a standard deviation of 22% of the monthly average costs for the MPPS plant suggests modest volatility in monthly costs, making the 'actual costs' for the MPPS plant more credible. It is noted that at a 75% efficiency level, the MPPS plant posts a positive profit with or without the inclusion of depreciation and excluding any external support.
- Marketing strategy to improve stock inventory levels is imperative as a notable difference was observed between the average monthly sales and production (unsold finished goods stock); where the former is significantly lower than the latter and KUC having the greatest difference. This result relates back to the marketing strategy modifications noted above – where all the composts need to increase their share of the fertilizer market through innovative approaches such as product

[4] It is important to note that these figures are significantly lower than the estimated cost figures and had high standard deviations, thus credibility of data questionable – with exception of the MPPS plant which had moderate volatility in the monthly cost figures.

differentiation, strategic partnerships for product distribution, result-driven product promotion, and repositioning of product brand.

There is a great opportunity for all the four compost plants to ensure long-term sustainability from the adoption of the recommended adaptations to their operational systems, however significant capacity development of the relevant stakeholders is required. The implementation of technological changes and best practices for plant performance improvement require the provision of skill enhancement training on related subjects (e.g. training on new technologies such as development of faecal sludge-based co-compost *(Fortifer)*) would further strengthen their capabilities. Additionally, the implementation of innovative marketing and business strategies require knowledge and competence training on product marketing, building customer relationships and strategic partnerships, product diversification, and promotion of the compost facility supervisors and other relevant officials.

Finally, the knowledge gap at the end-user level require the implementation of awareness and knowledge building programmes on both the monetary and non-monetary benefits of Best-Comp to farmers. Additionally, there is a lack of adequate awareness of MSW compost among stakeholder agencies and weaker linkages between MSW compost plant/production and grassroots officers. This requires training and awareness programmes on compost manufacturing process, quality certification and the benefits of MSW management programme to the environment and communities to stakeholder agency officers (Department of Agriculture (DOA), Department of Agrarian Development (DAD), grass root level officers (Agricultural Officers (AO), Agricultural Instructors (AI), and Agricultural Research and Production Assistants (ARPA) etc.).

1. Introduction

1.1 Overview of Research Project

Limited public funds to support waste management infrastructure and services has resulted in significant environmental pollution as the majority of the generated waste, whether collected or uncollected is often disposed off untreated in open spaces, water bodies and/or dumping sites (UNEP, 2005). The long-term effects of these practices include increased human health risk from communities' exposure to untreated waste and generation of significant quantities of greenhouse gas emissions in the form of methane. This situation is particularly exacerbated for cities characterized by a growing population and rapid urban migration. There are opportunities to address the dual challenge of waste management and soil depletion in developing countries through the safe recovery of resources from solid waste streams for reuse in agriculture. A paradigm shift in the sanitation sector towards cost-recovery through reuse is currently supported by many donors pushing for waste to wealth programs that involve both public and private sector participation.

Additionally, there is a global drive to reduce the use of synthetic fertilizers and to increase the use of organic fertilizers. The Government of Sri Lanka is promoting organic fertilizer as a 'healthier' alternative to chemical fertilizers (Department of National Planning, 2010). Municipal solid waste (MSW) is a major organic waste resource that is excessively available and yet to be exploited for its nutrient content capacity. Thus, there is a great potential to close the nutrient recycling loop, support a 'circular economy' and cost recovery within the waste sector and even to create viable businesses. The idea of closing the nutrient cycle by using municipal organic waste for urban and peri-urban agriculture is nothing new. Not only has it been practiced for generations in many countries either formally or informally, it has also been proposed and tried on a small scale as a green solution for modern cities.

However, very few successful cases have been noted and the majority of initiatives in developing countries recorded are small scale and seldom viable without significant subsidies. There are many challenges to recovering the organic fraction of MSW, and for the production of a competitive, high-quality compost product in a cost-effective manner. Currently, the low market demand for compost and the long-term financial sustainability of the industry, seems to be the major challenges. At present, the average cost recovery potential for medium and small scale compost plants is as low as a third of the operation and maintenance costs (Fernando et al, 2014). For example, the potential cost recovery value to be derived could possibly be greater if larger-scale compost plants are considered in the cities. The majority of plants in Sri Lanka appear to be financially unsustainable even with a low benchmark of 50% cost recovery. However, some plants in Sri Lanka perform well and achieve breakeven and even marginal profits as noted in the cases of the Balangoda and Weligama Municipal Compost plants with 100% and 106% cost recovery, respectively (Fernando et al, 2014); indicating the potential success that waste reuse initiatives can have in supporting the sustainability of the sanitation sector.

In view of the challenges noted above, this research project sought to analyze business-oriented approaches to waste management services, with the objective of enhancing the scale up of productive reuse of waste resources for increased sustainability of the sanitation value chain. This is mainly because the sanitation sector is traditionally viewed as a fully subsidized public service, resulting in poor and unsustainable levels of service (Evans and Drechsel, 2010; Koné, 2010; Rouse et al., 2008). The research project ("**Opportunities for sustainable municipal solid waste management services in Batticaloa: Strategies for improved resource recovery and reuse"**) thus aimed to support UNOPS' initiative to develop cost-effective and sustainable integrated MSW management services in the east of Sri-Lanka. It focused on four operational compost plants in towns in the eastern province of Sri Lanka: Batticaloa, Kattankudy, Arayampathy, and Kaluthavalai. The overall goal objective of this project aimed at providing recommendations on strategies for the recovery and productive reuse of MSW of these four compost plants in the Batticaloa district, with a view of ensuring the provision of sustainable waste management services by the respective local authorities (LAs). In that regard, the project aimed for outputs to include the following:

1. A review of documented successful business case examples and projects on nutrient recovery from domestic solid waste streams MSW.
2. Recommendations on adapted sustainable strategies, tailored for the recovery and productive reuse of MSW of the four compost plants in the Batticaloa district.
3. Recommendations on adapting existing training and capacity building initiatives of the local stakeholders involved with or responsible for the provision of waste management services in the Batticaloa district.

The 1st output provided a foundation and key learnings on international and local best practices (from technical and business perspective) to guide the development of sustainable strategies for the selected compost plants in Batticaloa in this study. This report presents the results focusing on outputs 2 and 3.

2. Methodology

2.1 Overview of Methodology

The two strategic thrusts of the research project were: (i) strong stakeholder involvement and (ii) applied action research with an economic (business and market) focus to make a sustainable business of waste reuse initiatives by LAs in the Batticaloa district. The research included an economic (business and market), and technical analysis to learn about the existing (and support further) operational (technical and business) strategies used by the LAs for municipal solid waste management[5]. The findings presented here are to assess the current sub-optimalities in the operational systems of the compost plants and identify sustainable strategies to address them. This represents important information for the LAs (waste management regulators/ service providers), who are constantly exploring a holistic approach in generating multiple benefits from waste reuse businesses.

In this regard, the activities focused on two main components:

a) **Technical assessment –** which focused on the technical optimalities of the compost production process along the entire value chain from waste (input) procurement to product finalization;
b) **Market and financial/business strategy assessment** – which focused on understanding the factors (e.g. market demand, marketing and pricing strategies) influencing the financial viability of the compost plants.

Under the two research components, a situational analysis was conducted as a first step to understand the current status of the operational systems of the 4 compost plants. Subsequently, accounting for different internal and external factors that influence performance, a scenario analysis was conducted to identify the most sustainable strategies to be adopted by the LAs. The report is thus presented based on the findings of the situational analysis comprising the technical, market and business strategy assessment; and similarly for the scenario analysis. The situational and scenario analyses were conducted using both qualitative and quantitative approaches.

2.2 Study Area and Data

The four compost plants, under consideration for this project, are located in the Manmunai North municipal council (Batticoloa Municipal Council – BMC plant), Kattankudy urban council (Kattankudy Urban Council – KUC plant), Mamunai Pattu Pradeshiya Sabha (Arayampathy – MPPS plant) and Manmunai South and Eruvi Pattu Pradeshiya Sabha (Kaluthavalai – MSEP plant) (Figure 1). Whilst these 4 urban councils represent relatively small areas of the district; they have shown high population density in comparison to other local authorities in Batticaloa. Among them, Manmunai North is the highest populated area in Batticaloa, and Manmunai South and Eruvil Pattu come in second; with Kattankudy and Manmunai Pattu coming in third.

Field surveys were conducted covering all four compost plants established by the UNOPS-led project in Batticaloa MC, Kattankudy UC, Arayampathy PS and Kaluthavalai PS. For the technical assessment, for all the compost plants, relevant key officials of the local authority (LA), for example, public health inspector

[5] For the purpose of this research project, waste management refers to the specific component of the value chain that focused on resource recovery from municipal solid waste (i.e. nutrient recovery).

(PHI), compost plant and solid waste management supervisor, compost plant workers, and sanitary labourers were interviewed using a semi-structured questionnaire, in addition to field visits made to the compost plants. Additional data was obtained from existing published literature, national statistics, existing databases with UNOPS, and information from UNOPS officers. Expert interviews were conducted to verify data and fill data gaps. In addition, for the market and business strategy assessment, agrarian service center officials and farmers were interviewed.

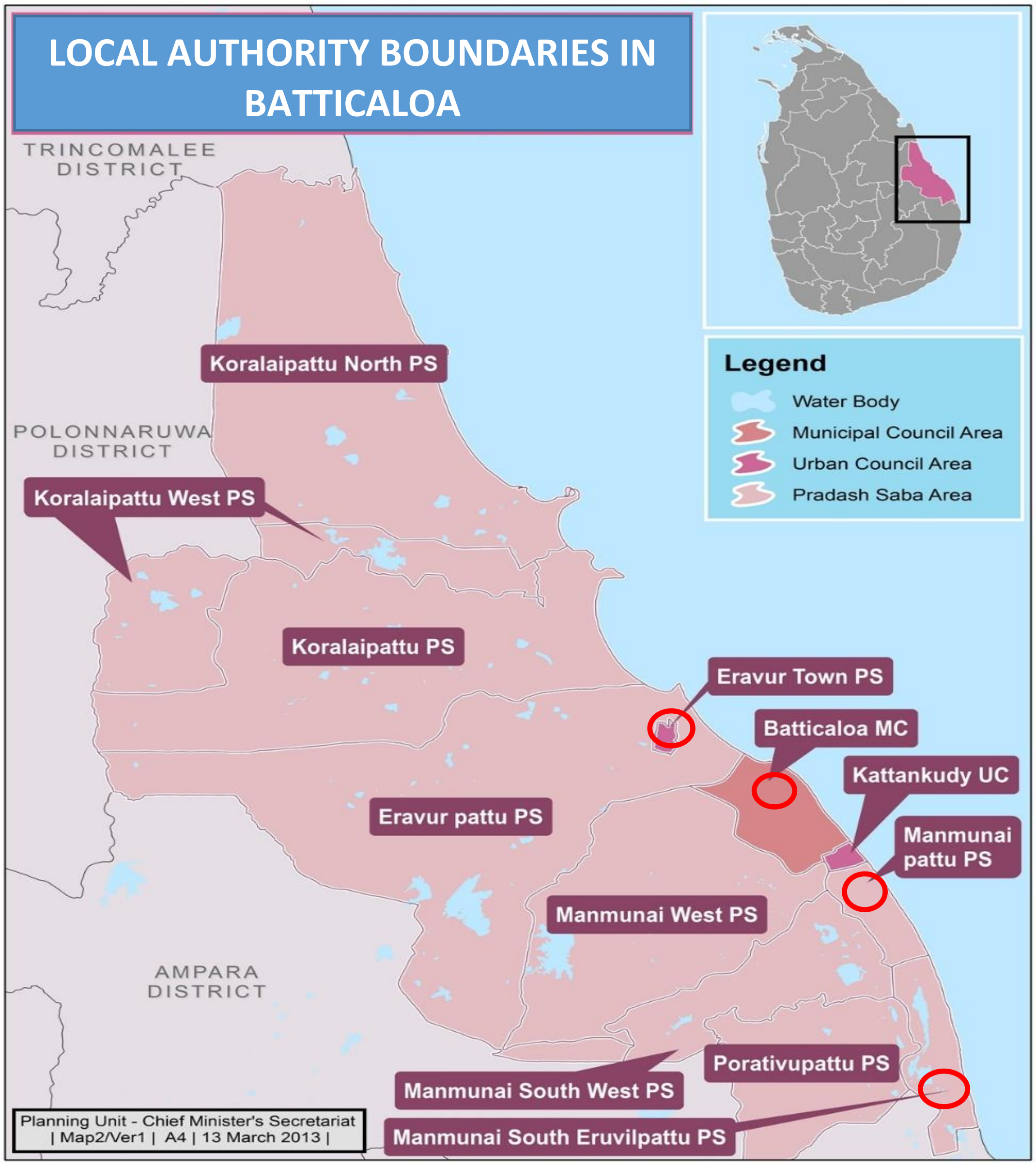

Figure 1: Map of the Local Authorities in Batticaloa
Source: http://www.ep.gov.lk/Images/LocalAuthBoun_Batticaloa.jpg

3. Key Findings of Situational and Scenario Analysis

The chapter presents the findings of the situational and scenario analyses comprising the technical, market and financial strategy assessment. The situational analysis was conducted using both qualitative and quantitative approaches; and similarly for the scenario analysis.

3.1 Technical Assessment

Composting is a cost-effective waste management (treatment) option given the waste in Sri Lanka, like most developing countries consists over 50% of readily biodegradable organic material (Hoornweg *et al.* 1999; MENR, 2007). Municipal solid waste (MSW) as an input material for composting is however not free of technical challenges, including: (a) high carbon but low nutrient content (especially nitrogen content) of the input material, (b) impurities and contaminants, and (c) less segregated nature (highly mixed nature), etc. In general, the MSW-based compost is oftentimes considered more as a soil conditioner than a fertilizer due to its low nutrient content. This limits its market demand and market potential for revenue generation, and in turn results in low cost recovery and invariably high rates of project failures particularly when external donor funding or other subsidies end. In this regard, to ensure the sustainability of the four compost plants under study in this project, it is imperative that the technical aspects of the operational system is assessed comprehensively to identify any sub-optimalities in the production process and subsequently provide recommendations on how to address these gaps.

The technical assessment was conducted based on the foundation of the compost production process. At the simplest level, the composting process simply requires the selection of a waste input, windrow construction, and turning and watering to allow break down into humus. Controlled and methodical composting is a multi-step and closely monitored process with measured inputs material (nutrients), water, and many process controls. The decomposition process is aided by optimum conditions (such as moisture content, particle size, C: N ratio) to confirm access to water, air, and food for microorganisms. The main activities along the production process are shown in Figure 2. A wide range of urban organic waste materials including catering waste, kitchen waste, market waste, crop residues from public places, and households can be used to produce compost. Specific challenges with compost made from urban waste, which would not be a concern with agro-waste composting, are: a) the limited control over input material quality and quantity, b) waste contaminations, and c) mixed nature of waste input. The process to control parameters and strategies to use in order to obtain a high quality output will be discussed under the components mentioned in Figure 2. All the four compost plants in the study consider a 10-week decomposition period (2 and half months) and 2-3 weeks curing period. Hence, the entire composting process duration lasts on average three months.

In the subsequent sections, we will analyze each stage of the production process for all the compost plants to understand how the specific processes are been performed. This enables one to identify any gaps in the operational processes and subsequently identify measures to improve the production process and invariably, plant performance.

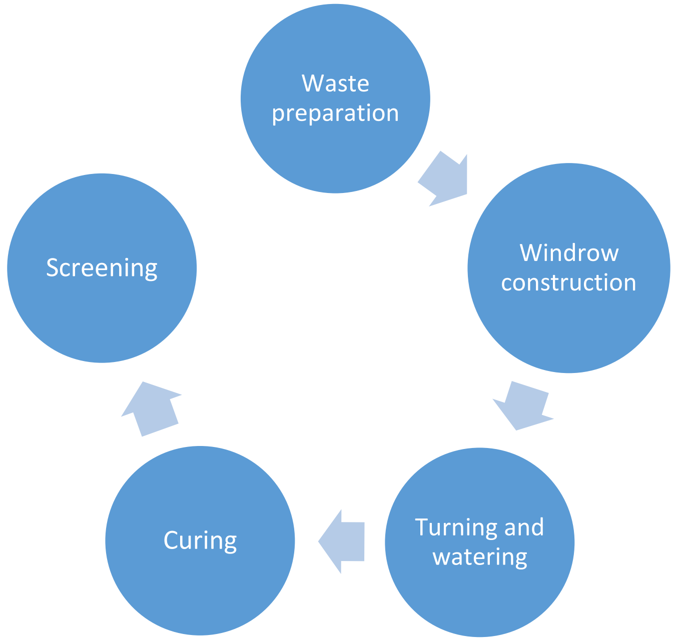

Figure 2: Key process activities considered in analysis

3.1.1 Waste preparation

3.1.1.1 Situational analysis

- Incoming waste and collection capacity

According to the waste supply data recorded at the respective four local authorities, all the local authorities collect waste in their respective localities at least 6 days per week, with the exception of KUC which collects waste 7 days a week, covering all localities. KUC and BMC are the most urbanized LAs, with the highest waste collection quantities and are equipped with a fitting vehicle fleet of tractors, converted three wheelers, and compactors. The other two LAs are less urbanized, hence the waste collection is relatively low. Table 1 presents the waste collection quantities and equipments owned and used by the LAs. MSW collection coverage in the four LAs is limited to urbanized areas, city centers, and commercial areas. This is not uncommon when compared to other LAs in the country and in the developing country context.

Table 1: Details on waste collection and resources

	BMC	KUC	MPPS	MSEP
Number of waste collection days / week	6	7	6	6
Total Daily collection capacity[2] T/day	52.5T	18.5 T	7.7 T	5.5 T
Tractor[1]	$4m^3$ (8) - 2018	$4m^3$ (8) - 2018	$4m^3$ (3) - 2021	$4m^3$ (4) - 2018
Compactor[1]	$7m^3$(1) - 2020	$7m^3$(1) - 2025	$7m^3$(1) - 2025	$7m^3$(1) - 2025
Three-wheeler[1]	-	$0.75m^3$(2) - 2020	-	-

[1]Vehicle capacity (number of vehicles) – replacement year
(Source: Local Authority Survey)

Figure 3: Modified Three-wheeler in waste collection fleet at Kattankudy.

According to previous studies, the organic content of the municipal waste in Batticaloa district is about 57% (source: SWM master plan for Batticaloa district), which is comparable to other studies conducted in low-income countries that reveal that over 50% of MSW is comprised of organic waste (e.g. Hoornweg *et al.* 1999). The conversion of all organic waste to compost is theoretically possible, with practical limitations pointing to economic, technical, and final product usage perspectives. Table 2 depicts the actual amount of MSW composted compared to the waste collection quantities at each LA. As discussed, local authorities collect waste for 6 - 7 days a week from different wards of their locality and a continuous waste supply arrive at the compost plants. However, only a fraction from the total waste collection transfers to composting from the total collection.

Table 2: Waste treatment and disposal at the different compost plants

Local Authority	Waste Collection (T/day)	Amount directed to compost plant (T/day)	**Amount of MSW composted (T/day)**	**MSW composted as a % of waste collected**	Amount to landfill (T/day)	**% disposed at dumping sites**
BMC	52.5	12	**2.6**	**5%**	49.7	**95%**
KUC	18.5	12	**4**	**22%**	14.5	**78%**
MP-PS	5.5	4.5	**1.2**	**22%**	4.3	**77%**
MSEP-PS	7.7	4	**1**	**13%**	6.7	**86%**

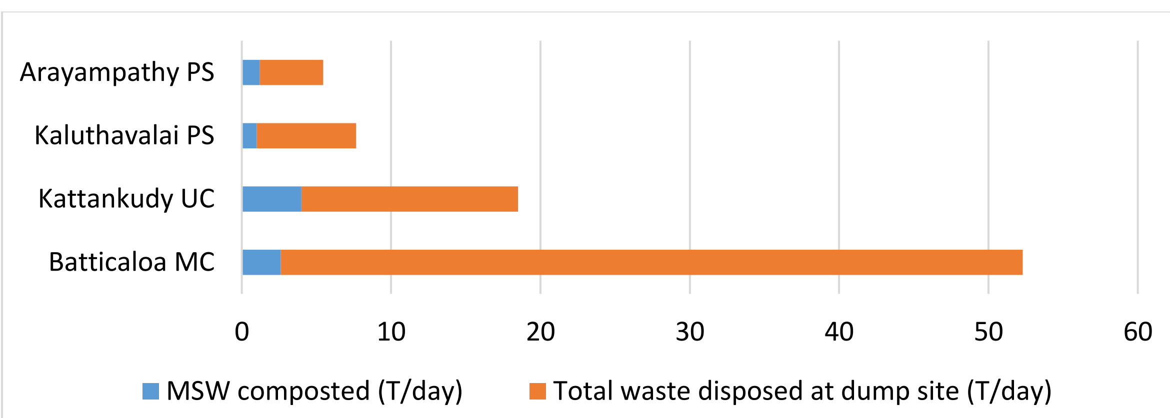

Figure 4: Quantity of municipal solid waste composted and disposed

Figure 4 shows that the proportion of MSW composted is substantially low compared to the theoretically compostable amounts (i.e. total organic content) which is about 50% of the waste collected in each LA. However, compost plants have been designed to process only a certain quantity of MSW (set production capacity). Table 3 depicts the design capacities and the operating levels of each compost plant compared to the design capacities. This is indicative of the relatively low performance of the compost plants given that they are operating significantly below their design capacity.

Table 3: Operating level of the compost plants

Compost plant	Design capacity (T/day)	Theoretically compostable potential amount (T/day)	Amount directed to compost plant (T/day)	Actual amount of MSW composted	Operating level
BMC	12	7.2	12	2.6	**36%**
KUC	12	7.2	12	4.0	**55%**
MP-PS	7	4.2	4.5	1.2	**28%**
MSEP-PS	7	4.2	4	1.0	**24%**

Based on interviews with the plant supervisors, it was noted that the compost plants receive different varieties of waste in high quantities. For an example, KUC and BMC plants receive bulky green waste and banana leaves/logs in large quantities. Due to the excessive quantities received, the compost plants cannot process/ use the waste on a daily basis. Although the plant supervisors adopt different strategies, significant volumes still remain unused. The MPPS plant receives high quantities of tree cuttings and is unable to use a significant percentage of it for composting. According to the input received by the four compost plants, a high percentage of input waste contains dry carbon elements that take a long time to decompose and produce a final compost product that is low in nutrients.

Figure 5: High volume of dry hard green waste arriving at compost plants

Based on observations during site visits, both the BMC and KUC compost plants receive waste loads sufficient to function in the design capacity. On the contrary, the MPPS and MSEP plants receive a relatively lower or equal amount of waste than the plants are designed to process. Current quantities of waste received at MPPS and MSEP plants are 4.5 T and 4 T daily reflecting only 64% and 57% of their design capacities respectively. Huge surpluses or uncontrollable backlogs of waste in any plant were not evidenced, because any extra quantities are diverted to dumping sites or only the amount meeting the operating capacity is diverted to the compost plant. Operating levels of the compost plants were estimated based on how much of the theoretically compostable waste is actually composted. According to the estimated current operating levels, all the compost plants appear to be operating under capacity. Inadequate supply of the 'correct' quality of waste is noted to be a key constraint that currently reduces the effectiveness of the compost plants.

- Sources of waste

Municipal solid waste is heterogeneous and generated from multiple sources. Due to the limited commercialized and industrialized nature of the concentrated LAs, households are the major waste generators. Other major waste sources are markets, hotels, restaurants, institutions (e.g. hospitals, universities) and commercial entities. Each LA has similar waste sources as presented in Table 4 below.
From the waste management perspective, organic waste types with the highest pollution potential should be the waste types targeted for composting; while from the technical perspective, waste characteristics and properties should be the key. From an economic point of view, the waste input that produces a compost product of the highest quality should be the driving factor for selection of waste stream. To acquire a sustainable and win-win situation in MSW composting industry, a balance should be sought among above-mentioned factors.

Table 4: Number of entities as sources of waste in four LAs in Batticaloa

	BMC	**KUC**	**MSEP**	**MPPS**
i. Domestic (number of households)	23,721	17,238	14,500	4,280
ii. Market	5	3	6	2
iii. Slaughter house	1	1		1
iv. Hotels/ restaurants	55	119	34	3
v. Hospital	3	1	2	1
vi. Commercial /Institutional	44	33	15	35
vii. Food processing industries	-	-	-	-

- **Waste Segregation**

Another major challenge of recycling organic municipal solid waste is the mixed nature of the waste. Mixed waste leads to difficulties in the production process and low quality outputs. Source segregation of waste stands as the best option, but in a low-income country context, it is evidenced as difficult to succeed and maintain sustainably in long term. However, successful local strategies are also demonstrated in local context as shown in Box 1. With the introduction of UNOPS compost plants in conjunction with North East Coastal Community Development Project, the concerned local authorities in Batticaloa have encouraged

Box 1: Successful source segregation case studies

Balangoda Urban Council – Balangoda urban council has imposed a tax on non-segregated waste for commercial institutes. If the waste is not segregated, a collection fee is charged and the segregated waste is collected without any additional charges.

Kaduwela Pradeshiya Sbaha – Kaduwela Pradeshiya Sbaha has imposed source segregation rules on households. In this case, no charges are imposed. The collection only covers segregated waste, and the council does not collect non-segregated waste.

a waste source segregation policy, aiming separating waste in to two fractions as biodegradable and non-biodegradable.

Table 5 and Figure 6 show the present scenario of waste segregation practiced by the LAs. It is noted that the segregation level is poor in Batticaloa municipal council compared to the other LAs, probably due to the difficulty of managing higher quantities of waste collection in Batticaloa municipal council.

Table 5: Solid waste vs. Segregated Waste Collection in four selected LAs

LA/ Compost plant	SW collected (T/day)	Segregated waste collected (T/day)	Percentage (%) of segregation at source
BMC	52.5	12	23%
KUC	18.5	12	65%
MPPS	7.7	6	78%
MSEP	5.5	4.5	82%

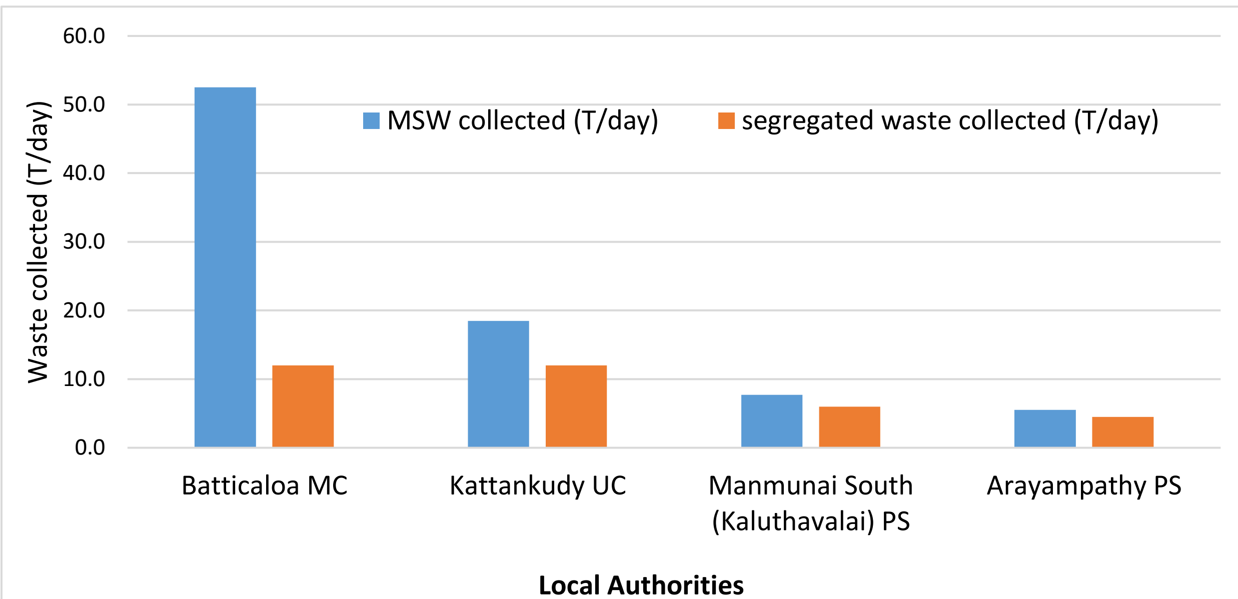

Figure 6: Current level of segregation practices at LAs

The daily incoming segregated waste to the compost plant is presented in Table 6. Considering the types and quantity of waste coming to the compost plant, the amount of food and market waste is relatively low, i.e. 8%, 17%, 22% and 25% of the total waste received at BMC, KUC, MPPS and MSEP, respectively. Bulky green waste, which mostly consists of tree cuttings (banana leaves and trunks) amounts to 75%, 50%, 67% and 75% at BMC, KUC, MPPS and MSEP, respectively. This indicates that most of the waste received at the compost plant are not source segregated, but are available in segregated nature (such as market waste). Most of the waste received by the compost plants is long-term biodegradable wastes in nature and high in carbon (and less in nitrogen).

Table 6: Daily incoming segregated waste input at four plants by type (in tons)

	BMC	KUC	MPPS	MSEP
Food & Market Waste	1	2	1	1
Bio Solids	-	-	-	-
Bulky Green waste	9	6	3	3
Agricultural Waste	-	1.5	0.5	
Any other (Banana load)	2	2.5		
Total	**12**	**12**	**4.5**	**4**

- **Particle size of waste**

Shredding of raw materials is beneficial, particularly when composting fibrous materials and high carbon waste material such as leaves, woody plants, sticks, and tree cuttings, etc. Shredding exposes a greater surface area, which makes it more susceptible to bacterial activities or biodegradation. Large pieces of wood or leaves do not decompose quickly in a compost pile, and insufficient oxygen in the center of a wood chunk or a wad of leaves do not permit rapid aerobic decomposition. Shredding material makes it uniform in size, aerates, and makes it easier to handle, and smaller particles enable uniform biodegradation activities. Generally, the best size particles for composting are less than 2 inches or 50 mm in the largest dimension. Initial shredding of all material is not necessary. Often, the best practice is to shred only large pieces of organic; especially long term degradable materials (i.e. large, high carbon feed stocks may require shredding to speedup decomposition). Vegetative and herbaceous matter (short-term biodegradable high moist) should not be ground up as it can turn soggy or make into a paste. High moisture content of these materials makes them more difficult to manage in aerobic composting. High moist waste materials such as vegetable waste breaks down quickly during the composting period, hence shredding is unnecessary.

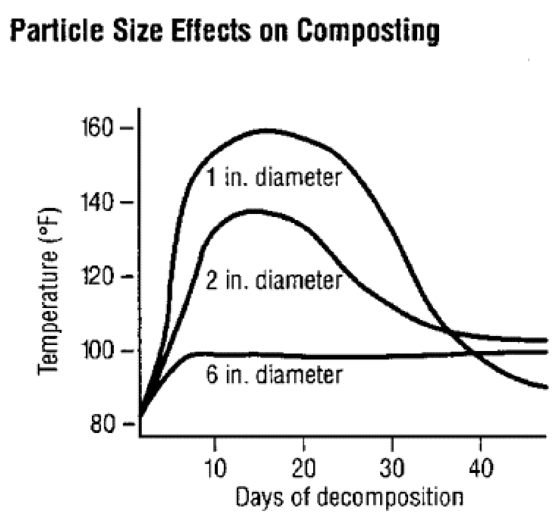

Figure 7: Compost process with particle size

Source: http://whatcom.wsu.edu/ag/compost/fundamentals/needs_particle_size.htm

- **Shredding of bulky green waste**

All four plants receive large quantities of banana trunks and leaves, and they are manually shredded into small parts. The Batticaloa plant has shredding machines, which is an efficient way to reduce particle size. Same shredding machine can be used on tree cuttings and on hard bulky materials. As shown in Figure 7, the optimum particle size can be identified as 0 – 25 mm.

Figure 8: Shredding methods used at compost plants

3.1.1.2 Scenario Analysis

- Quality of the waste Input

If the proper process is maintained, the final compost product quality mainly depends on the quality of the input material. Therefore, a compost plant needs to maintain certain nutritional parameters in its waste inputs. As illustrated in Figure 9, high-carbon wastes such as tree cuttings have low composting potential compared to manures, food waste, etc. from a technical point of view. As per Figure 9, waste with high potential for composting has the highest environmental and health impact, if linked by a pathway. Additionally, waste with high potential for composting has the highest nutrient densities, which makes the high value final product attractive to farmers. In such cases, the use of short-term biodegradable waste in composting should be promoted, as it has the potential to holistically fulfil the technical, health, environmental, and economic aspects.

Figure 9: Quality guideline for different types of input for composting

Source: Department of Environment Affairs (2013) The national Organic Waste Composting Strategy,

- **Waste Segregation**

In regards to addressing the waste segregation challenge, a credible option is to collect the waste from short term degradable organic waste sources in large quantities, which can be found in source-segregated manner; i.e. market waste, food processing industry waste, etc. Another option is manual waste segregation, which is however labor-incentive and costly. According to the Balangoda compost plant, which is one of the best MSW compost plants in the country, basic sorting of 4 tons of garbage requires 3 man hours. Accordingly, KUC and BMC compost plants will require 9 man hours for basic waste sorting per day and the other two plants 4-5 man hours per day. The BMC and MPPS compost plants sort the daily collected waste in one day, whilst KUC and MSEP plants need two days for sorting. According to the interviews conducted with the employees of the compost plants, at least 3 or 4 workers operate in sorting activities on daily basis. The lack of sufficient workers for waste sorting has been a challenging factor for the compost plants. Table 7 shows that food waste is in low amounts and this translates into low N-content materials and high C:N ratios in input materials, which is unfavorable for the composting process and quality of the final product.

High Nitrogen Materials

Horse manure	30:1	Sewage sludge	6-16:1
Swine manure	30:1	Food scraps	15:1
Cattle manure	19:1	Broiler litter	14:1
Grass clippings	19:1	Vegetable wastes	12:1
Turkey litter	16:1		

High Carbon Materials

Newsprint	398 - 852:1	Paper pulp	90:1
Corrugated cardboard	563:1	Leaves	40 - 80:1
Sawdust, wood chips	442:1	Fruit wastes	35:1
Bark	100 - 130:1		

Source: Rynk, R. *et al. On-Farm Composting Handbook*, Northeast Regional Agricultural Engineering Service, NRAES-54, Appendix A, Table A.1, 1992.

To obtain the preferred combination, windrows should be prepared with the best match combination of nitrogen and carbon composition. According to the composition of separated waste collected by the four LAs, the majority of the waste contains woodchips, bark, and tree branches, which contain high carbon content. Food, market waste, and green agricultural waste contain high nitrogen content but are low in supply. The preferred C:N ratio range for composting is 20:1 or 30:1, and as a thumb rule, this translates into one portion of green and one portion of brown waste, which is unlikely to be achieved with the present waste supply. Increasing short-term degradable high N nutrient waste is a major challenge that needs investigation. Observing the input material and low supply of food and short term biodegradable waste evidence low degree of separation at sources such as institutes, hotels, and households.

The compost plants can consider the following two approaches to address this challenge:

a) Improve source segregation allowing high amount of short term biodegradable waste,
b) Identify high nutrient waste sources such as manures, fecal sludge, etc.

Waste management highly encourages separation of waste and management. A compost plant should target the organic waste with high pollution potential such as market and food wastes, which result in higher positive environmental impacts such as reduced leachate and landfill gas released compared to high carbon waste such as tree cuttings and dry leaves with low pollution potential and it should be the second option or supplementary input material. The identified potential high nutrient waste sources are listed in Table 7 below.

Table 7: Potential high nutrient waste sources

Source	Availability	Competition	Price	Continuous or Seasonal	Recommended for
Segregated Hotel and Restaurant waste	There are large volumes of waste already been collected.	None. Sole responsibility of MSW collection belongs to LAs. Therefore they can enforce regulations to avoid mixing waste at hotels	No	Continuous	All four plants
Lagoon Algae	Lagoon covers a total area of approximately 135.5 square kilometers, hence, a large quantity of algae would be available	So far, no. During lagoon cleaning, the residual algae become part of MSW. Therefore, LAs have easy access to them.	No	Once collected it will take time to grow, hence the supply would be seasonal.	
Livestock waste	Batticaloa has a large quantity of livestock available (cow, buffalos, goat, and chicken farms).	High. There is demand for cow dung and other animal waste. Hence, accessing these might need some competitive offerings to livestock farmers.	Rs. 3000-6000 per ton	Continuous	BMC MPPS MSEP KUC
Fish Waste	BMC area has produced 6300 MT, KUC 1348 MT, MP-PS- 3460 MT, and MSEP-PS has produced 1320 MT of fish harvest.	So far, no. Fish waste is considered as market waste. Hence LAs have direct access to whatever is available in their locality.	No	Continuous in most of the dry months	BMC MPPS MSEP KUC
Fecal sludge	All the households and commercial entities have onsite sanitation systems	No. Since the majority of households in the localities have demand for desludging, LAs can access faecal sludge easily.	No	Continuous	BMC MPPS MSEP KUC
Glyricedia/Giniseria	Extensive land spaces in plant premises that cultivate it.	No. There is sufficient space in compost yards to have a small cultivation of GS.	No	Continuous	BMC MPPS MSEP KUC
Husk ash	Paddy farming is the major agriculture activity with large extent in Batticaloa.	No	No	Seasonal	BMC MPPS MSEP

3.1.2 Windrow Construction

3.1.2.1 Situational analysis

The next step in the compost production process is the construction of the windrows. After the waste has been prepared, it is transferred into compost windrows. The size and shape of the windrow depends on the composting process adopted in the plants. All of the four compost plants use the turning windrow composting method. Compared to other composting techniques, this method requires lower start-up cost, expertise, services, and operational cost. Additionally, the climate condition in Batticaloa and in Sri Lanka provides the required environmental conditions such as temperature and humidity levels to use turning windrow composting method successfully. No strict dimension requirements are required for windrow composting, but different guidelines provide different standards. The method used by most plants involves building a heap to the height of 1.5 m with a base of 2 m by 2 m, tapering up to about 1.2 m. Surface area to volume ratio (SA/V) of compost piles is important to increase the process efficiency. SA/V is expected to be less than 1 in general for a proper process. However, Malwana *et al.* (2013) showed

SA/V can be as high as 5 and still would provide an efficient process. In essence, the results indicated the lowest windrow dimensions could be 1 m height and 1 m width.

TABLE I: PILE DIMENSIONS AND SURFACE AREA/ VOLUME RATIOS OF TH SELECTED PILES

Pile No.	Height of the pile (m)	Width of the pile (m)	Length of the pile (m)	Surface area of the pile (m^2)	Volume of the pile (m^3)	Surface Area/Volume ratio
A	1	1.5	3	13.5	4.5	3
B	1	1	2	8	2	4
C	1	1	1	5	1	5
D	0.5	1	2	5	1	5
E	0.5	1	1	3	0.5	6
F	0.5	0.8	0.8	2.24	0.32	7
G	0.5	0.5	1	2	0.25	8

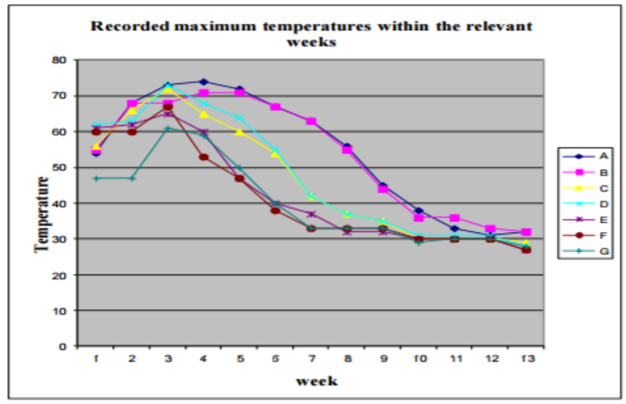

Figure 10: Windrow dimensions and composting process (source: Malwana et al. (2013))

Table 8 indicates the dimensions of the piles commonly constructed at each compost plant. According to the values it can be determined that the SA/V ratio is always less than 1 which theoretically ensures better conditions for process efficiency. Malwana et al. (2013) showed SA/V ratios up to 5 can be used successfully. However, it was observed that the big piles are practically difficult to manage when it comes to the turning of piles as all the plants are manually turn the piles except for the BMC plant which uses a skid steer loader (BOBCAT). Moreover, previous studies recommend that the size of the windrow can be increased to provide higher temperatures in cold weather or decreased to keep the temperatures from becoming too high in warm weather.

Table 8: Windrow sizes practicing at each compost plant

LA Compost plant	**Quantity of one pile (t)**	**Size of one pile (L*W*H)**
BMC	3.6	3m* 1.5m*2m
KUC	8.0	4m*2m* 2.5m
MSEP	8.0	4m*2m* 2.5m
MPPS	3.2	3m* 1.5m* 1.8m

**Assuming 400 kg/m^3*

3.1.2.2 Scenario analysis

Given the hot weather conditions in the Batticaloa region, it is advisable that the pile sizes are kept at minimum required levels to maintain optimum conditions for composting. It is recommended to limit the windrow height to 1 - 1.5 m. In general, the first layer is bulky material to improve drainage. Then, additional alternate layers of low nitrogen and high nitrogen material are added; and finally the windrows are covered with a bulky material.

Additionally, as previously noted Batticaloa has hot dry weather during most of the months, and heavy rains during rainy season. Both these extreme weather conditions do not provide favorable conditions for uncovered windrow composting. The BMC plant is the only plant that practices covered piling throughout the entire compost processing. KUC plant practices open space composting at the initial stage of the process and only at the later stage are the piles transferred to a covered space. On the other hand, both the MPPS and MSEP plants do not have covered spaces to raise the compost piles, thus only practice open-space composting. Generally, the practice is to raise new piles in outdoor areas and transfer slightly matured compost piles that are closer to process completion, to indoor areas.

Figure 11: Unmanageable Windrows at MPPS and MSEP plants

Experiences from other compost projects in the country (e.g. Pillisaru project) reveal that open windrows during the initial stage is successful. However, after the initial stage, windrows need to be moved to roofed/ covered areas to ensure an effective process. This is a requirement in the case of the MPPS and MSEP compost plants, especially given the heavy rainfall in the area. High rainfall can raise the moisture content higher than the optimum, leading to a low oxygen environment (i.e. anaerobic environment). Additionally, high exposure to sunlight raises the need of watering of the piles, which in turn require more frequent turning of the piles and invariably increasing the operational cost. Thus, undercover composting is preferred in order to maintain the controlled conditions for effective composting, and for which all the compost plants with the exception of the BMC plant need to consider in the adaptation of their operational processes.

3.1.3 Turning and Watering

3.1.3.1 Situational analysis

- **Watering for piles**

Watering is an essential component of the composting process since it is used as a necessary condition for the decomposition process. In general, it is recommended to have about 50-60% of moisture content in piles to allow accelerated microorganism activities (Sherman, 1999). Low moisture content can reduce microbial activities. At 40% moisture content, microbial activities start decreasing and eventually cease at 20%. Moreover, microbial activities are reduced at higher moisture contents beyond 60% due to low availability of oxygen. Moisture can quickly dry up with blowing dry winds and high average air temperature in Batticaloa. Hence, maintaining a consistent moisture content in a pile is challenging. As a practice, the employees of all four plants watered the newly built piles, and decomposition stage piles twice a day; once in the morning and once in the afternoon (normally at 8 am in the morning and 4 pm in the afternoon). The field study revealed that the BMC compost plant consistently maintains a 40-60% moisture content throughout the composting process. The KUC plant however starts with less than 40% moisture in the 1st week, and then increases to 50%, and gradually reduces to less than 30% in the 8th week. The MPPS and MSEP plants follow a similar approach, where moisture content reaches 60% in the 3rd week and reduce to less than 40% in the 8th week.

- **Turning**

Temperature of new piles (only 1 week old) at every plant was noted to be at least 50°C (Table 8). The BMC plant reported the highest pile temperature at different stages between 50 and 60°C. The reported MPPS plant piles reported high temperature readings during the entire process period, while the KUC piles had relatively lower temperature levels among all the four compost plants. Windrow temperature is an indicator of the level of microbial activity, with a higher temperature indicating high activity levels. Turning is another essential aspect of windrow composting, which allows windrow ingredients to be mixed, moisture to be well distributed (normally added during turning), improve air supply and to maintain high temperature levels and resulting high levels of microbial activity. Only the Batticaloa plant uses bobcat machines for windrow turning, while the other plants use manpower and manual tools for turning. In general, a plant employs at least 3-4 workers for 3-4 hours per day on average for windrow turning. The frequency of turning is in regular intervals in all the plants; i.e. 10 or 14-day turning cycles. Since the decomposition is extended to 10 weeks, one pile is turned 5 to 7 times on average during the process, according to the turning frequency.

Table 8: Turning frequencies and time taken for composting

Plant	**Turning frequency**	**Decomposition period**	**Curing period**
BMC	Once in 10 days	10 weeks	2 weeks
KUC	Once in 14 days (short term)/ once in 21 days (long term)	10 weeks	3 weeks
MSEP	Once in 14 days	10 weeks	3 weeks
MPPS	Once in 10 days (short term)/ once in 15 days (long term)	10 weeks	2 weeks

3.1.3.2 Scenario Analysis

- **Watering for piles**

For the stage of watering of the piles, the BMC plant was noted as the only plant with moisture content at the optimum range during week 1. All the other LAs have lower moisture content than the optimum range. However, at week 3, the moisture content improved in all plants. At the initial stage, regular moisture content inspection and addition is necessary and measurable using a digital meter or a field measuring method as shown in Box 2 and should be considered in the adaptation of the production processes.

Box 2: Squeeze test for moisture content

A simple squeeze test can be used to monitor the in-situ moisture content of compost. A few handfuls of compost grabbed from different areas in the pile is squeezed and:

- if water is dripped from the palm; then moisture content is considered to be > 60%
- If compost leaves the palm wet but does not release more than a drop or two of water; then moisture content is considered between 50-60% (or optimum)
- If compost falls apart, moisture content < 40%;

Table 9: Field measurement of moisture at different stages of composting

	Moisture content (%)				
Compost plant	**3 days**	**1 week**	**3 weeks**	**5 weeks**	**8 weeks**
BMC	**<40%**	**>60%**	**-**	**<40%**	**<40%**
KUC	**-**	**<40%**	**50%**	**<40%**	**<30%**
MSEP	**-**	**<40%**	**60%**	**40%**	**<40%**
MPPS	**<30%**	**<40%**	**60%**	**40%**	**30%**

- **Turning**

Pile temperature is a determining factor for the turning of the windrows rather than having fixed turning intervals. During the initial stage, high temperatures require frequent turning and later in the process, reduced temperatures require low frequency in turning. The first step is to move the material from the outside of the windrow to the middle, where it decomposes more quickly as presented in Figure 12. The second goal is to loosen and fluff the material, so it will be more porous and air can move through freely. First, flip the top of the windrow over just beyond the existing windrow, and second, take the compost from the bottom of the old windrow and place it on top of the new windrow. Then, let the compost cascade out of the loader, to keep it as loose as possible.

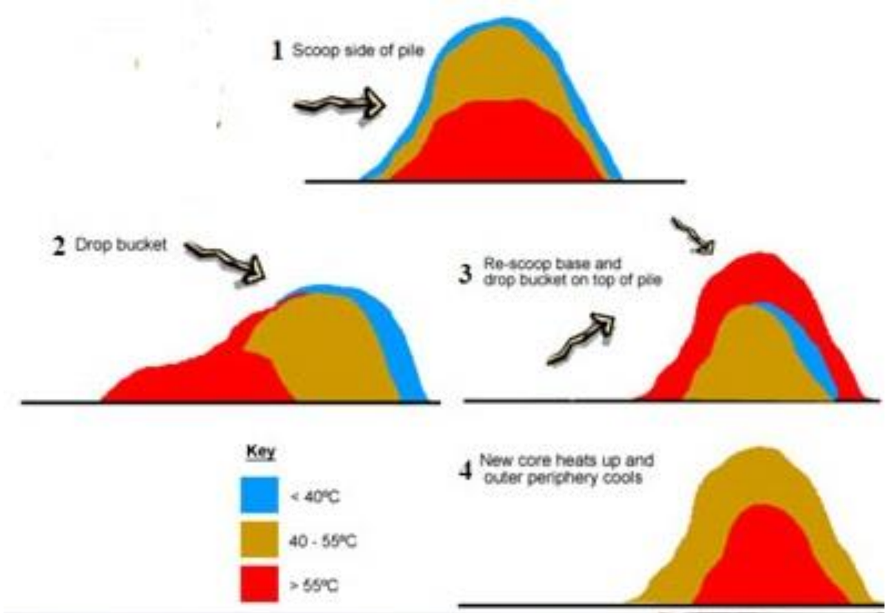

Figure 12: Turning of compost windrows

Turning should occur whenever the temperatures exceeds 60°C, or drops below 33°C during the composting phase. If the composted material stays in this range on its own, regular turning can further accelerate decomposition by mixing the material, improving aeration, and exposing new surfaces. As decomposition proceeds and the compost becomes more stable, frequent turning becomes less important. At low temperatures, if the compost has become anaerobic and smells, turning will temporarily add oxygen. Compost turnings can also represent ways to address any challenges related to too large windrows, too much water, or too much nitrogen.

Table 10: Field measurements of temperature at different stages of composting

Compost plant	Temperature (^{0}C)				
	3 days	**1 week**	**3 weeks**	**5 weeks**	**8 weeks**
BMC	>50^{0}C	>50^{0}C	>60^{0}C	>60^{0}C	>50^{0}C
KUC	-	>50^{0}C	40^{0}C	40-45^{0}C	30^{0}C
MSEP	-	>50^{0}C	>50^{0}C	>50^{0}C	30^{0}C
MPPS	-	50^{0}C	50^{0}C	60^{0}C	50^{0}C

3.1.4 Curing

3.1.4.1 Situational analysis

Matured compost is a material with slowed biological activity. Most molecules have been broken down, with a resulting complex organic material. A fine textured, dark color, and a rich earthy smell often characterizes a matured compost. The final products are simple, stable molecules, which make up the humus-like matrix of nutrients and organic matter or compost. While this finished product is highly beneficial to plants, some intermediate stages of the composting process may temporarily produce compounds, such as organic acids, that can be harmful to plant growth. Immature composts continue to break down once they are incorporated into the soil. This can affect plant health by consuming or tying up two resources that growing roots need. The high level of microbial activity in unfinished compost requires a large intake of oxygen, and the microbes may pull this from the surrounding soil, essentially suffocating the roots. The high carbon to nitrogen ratio (C:N ratio) of immature compost also means that, as the carbon compounds continue to break down, microorganisms will draw on soil nitrogen to assist in the process, leaving the root zone temporarily nitrogen poor. Curing follows the active high temperature cycle in composting, and begins roughly, once microbial metabolism in the pile is not producing sterilizing heat, and the pile once again becomes a favorable environment for beneficial compost life forms. When curing is completed, the compost should be stable, or at least more stable than before. The primary benefit of curing is to lower the phytotoxicity, improve the pH, and lower the C/N ratio. The primary phytotoxic materials are usually volatile organic acids from partially decomposed feedstock.

In all of the compost plants, when the pile completes its curing period, its moisture content is checked. If the moisture content of compost is reduced to suit the packaging conditions, the pile is considered ready for sieving. The workers break down the compost piles for the last time using manual tools, which are used for turning. If the supervisor decides the compost is not ready, s/he will advise the workers to leave the pile for a few more days to extend its maturing process, or ask to mix with another pile at one week before maturity. However, this can delay the entire production process since the final production halts until the next pile matures. Piles with high moisture content are turned again and laid on the floor to facilitate quick drying.

Figure 13: Under-prepared pile waiting to be mixed with next matured pile at KUC plant

Figure 14: Pile laid on the floor for drying before compost generation at BMC plant

3.1.4.2 Scenario analysis

The feedstock quality of the composts' parent material, the manner, and the degree of stability of the decomposing organic matter when curing begins, will influence the time required for curing to stabilize the compost. It is thus important that all the compost plants pay close attention to the preceding activities in the compost production process as these greatly influence the curing period which in turn significantly affects the overall operational performance of the plant. Curing time can range from 21 days to months; many researchers recommend at least a month. The bioassay performed by sprouting seeds can help to predict the success of the compost curing. For an example, Gariglio *et al.* (2010) confirms that the germination bioassay using lettuce seeds was adequately sensitive and identify the presence of phytotoxic compounds in compost.

3.1.5 Screening

3.1.5.1 Situational analysis

When composting various types of organic residues derived from yard trimmings, wood wastes, and segregated collection of MSW, the finished compost product usually contains a certain amount of foreign material, such as small plastic film particles, rocks, etc. that must be removed to improve the compost quality. Separation by screening is generally more difficult with a product material with high moisture content. All the four compost plants use the same screening technique, a mechanically-driven rotating screener. After completing the curing period, the matured compost is screened. All the plants with the exception of the BMC plant have only one screening machine. Generally, it requires two workers to conduct the screening operation. Any inorganic residual such as plastics and bigger particles such as sticks etc. are removed from the screen. This screening procedure was noted to be well performed at all the compost plants.

Figure 15: Compost screening at KUC plant

Beyond these process activities, it is important that the final compost product actually meets the needs and requirements of the end users (agricultural producers). In that regard, it was important to understand the perceptions of the current users of the compost produced by the plants. Based on farmer interviews, three main improvements to the compost product were noted: a) improvements to the nutrient value, b) reduced sand content, and c) reduced inert content (e.g. glass particles, plastics particles). Of these 3 factors, improvements of the nutrient value was the most important factor to the farmers, as presented in Table 11. Inert content can be reduced substantially while promoting source segregation. One of the drawbacks with less segregated waste is high impurity contents in the final compost product.

3.1.6 Scenario Analysis

Improvement options to the waste input material have been noted above. Similar to the level of impurities, high sand content in the final compost product is also a key issue. Street sweepings contain a large percentage of sand, which could be the main source. In addition, domestic garden waste and greens from public places would contain high sand contents. Increased waste segregation and targeted ‘high quality’ waste streams can be used to mitigate this challenge and improve the final compost product quality. Additionally, blending the main waste input with raw materials with low impurities (such as manures) can substantially reduce the sand content.

Table 11: Farmers' perceptions on possible improvements to compost

Consumer need	Frequency	%
Increase nutrient value	71	59%
Reduce sand content	35	29%
Reduce inert content	22	18%
Reduce odor	5	4%
Increase particle size	3	2%
Reduce price	3	2%
Proper labelling	3	2%

There are two main avenues that can be implemented to increase the nutrient levels of the compost product: (a) co-composting with high nutrient waste material such as fecal sludge and (b) blending with mineral fertilizer or other resources such as rock phosphate. The majority of households and institutions use onsite sanitation systems, thus the LAs have access to significant quantities of 'uncontaminated' fecal sludge that can be used to produce a high-nutrient co-compost. The International Water Management Institute (IWMI) has developed such a product called Fortifer, a nitrate fortified and pelletized, faecal sludge and MSW co-compost; which addresses the current challenges associated with using 'regular' compost or even dried faecal sludge, perceived to be bulky, low nutrient content, related health risks from product. The main approach is to dry the septage followed by aerobic composting of the dewatered sludge, which sanitizes and reduces its volume. Although faecal sludge can be processed alone, co-composting with another organic waste, such as organic municipal waste is more common, as it improves the composting properties, in particular the carbon–nitrogen ratio and moisture content. For further details on nutrient enhancements, please refer to Annex 1. In addition, the pelletizing process can be used as a value addition to the final product and further details on pelletizing is presented in Annex 2. This technology can be easily adopted by the four compost plants to improve the product currently being produced, which will in turn improve the sustainability of the plants.

3.2 Market Assessment

Market demand is a challenge that a lot of compost plants often face in developing countries. This has implications for their financial viability and invariably, long-term sustainability. The question of whether a demand actually exists and the price end-uses are willing to pay for the product needs to be explored as demand, even among those with limited resources, is not automatic. Additionally, the adoption of effective marketing and pricing strategies can help businesses mitigate the negative effects of competition and ensure business sustainability. In that regard, an assessment was conducted for all the compost plants to understand their business from a market perspective to identify ways for improvement.

3.2.1 Market demand for MSW compost

- **Farmers' perception of MSW compost**

Both quantitative and qualitative techniques were used to assess the farmers' wiliness to use and pay for MSW compost. A survey of 120 farmers indicated that the majority (95%) were willing to use compost. Only 2.5% of the farmers noted unwilling to use compost in the future. This may be attributable to their unawareness of yield guarantee from compost use. Product quality was identified as an important factor influencing farmers' purchasing decision of MSW compost. The majority of interviewed farmers (86%) strongly agreed that certification and quality assurance were influential factors for compost purchase.

Price was another significant factor influencing their purchasing decision. The farmers noted that the current price of compost (Rs. 8/kg – wholesale price; Rs. 12/kg – retail price) was higher than they would like to pay and preferred to pay Rs.6 -7 per kg, which is lower than the current wholesale price being offered by the compost plants. This is an important finding that the compost plants have to take into consideration for their market expansion strategies. Compost plants can benefit from economies of scale from increased production which can allow them to reduce the compost price. The results indicated that farmers seek to minimize transportation costs, thus a convenient location where they can purchase fertilizer for farming activities is crucial. In support of this assertion, the results reveal that 69% of the farmers perceive a convenient location to buy fertilizer as a significant factor in their purchasing decisions as there are limited to no compost selling centers not available in their neighborhoods. Hence, large quantities of compost need to be transported at an increased cost.

In most cases, farmers have limited experiences with the use of compost. From this perspective, farmer-to-farmer promotions could enhance the use of a particular fertilizer product. About 70% of the farmers were likely to purchase fertilizer if it was recommended by trusted sources (recommendation from agriculture instructors/officials) and a higher percentage was observed if they knew someone who was currently using it for farming activities. This result suggests that farmer-to-farmer experiences could facilitate the adoption of compost.

Table 11: Assessment of key factors influencing farmers' purchasing decisions of organic fertilizers

	Respondents' assessment of questions – Likert scale ranking (N=121)				
	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Assessment questions	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents
Easy access to sellers	55.0	14.2	15.0	6.7	9.2
Access at farm gate	40.0	16.7	15.0	11.7	16.7

Availability	51.7	27.5	9.2	4.2	7.5
Who distributes	25.0	10.0	26.7	13.3	25.0
Cost/price/affordability	60.0	10.8	9.2	3.3	16.7
Certification/quality assurance	76.7	10.0	3.3	3.3	6.7
Past experience of using	58.3	17.5	5.8	6.7	11.7
Recommendation from agriculture instructors/officials	50.8	20.0	9.2	9.2	10.8
Recommendation from fertilizer sellers/dealers	5.0	12.5	29.2	21.7	31.7
Recommendation from neighbor/friends (someone used it before)	23.3	15.8	18.3	18.3	24.2
Recommendation from Farmer organization	47.5	26.7	14.2	4.2	7.5

- **Farmers' perceived constraints to buy BEST–COMP as fertilizer**

The majority (77%) of farmers noted the quality of the compost produced by the plants in this study (BEST-Comp) was sub-par. They did not have confidence that the use of BEST- Comp would result in improved crop yield. Additionally, 82% of the farmers agreed that the low nutrient levels of the compost product was a major constraint in the use of compost. Another major concern was physical contaminants, where 70% of the farmers strongly agreed that this was a constraint and limited their use. The irregular supply and distribution of compost was another major constraint noted by the farmers. Although the price of BEST-comp is determined on a competitive basis, 50% of the farmers noted that affordability/price was as major constraint. These results suggest that the three key major marketing elements: product, place and price related to BEST-COMP need to be revisited and revised.

Table 12: Farmers' perception of constraints in using MSW compost

	Respondents' assessment of questions (Likert scale ranking) (N=121)				
	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Assessment questions	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents	% of surveyed respondents
Availability for regular consumption	54.2	22.9	8.3	2.1	12.5
Access to distribution places	54.2	27.1	8.3	4.2	6.3
Continuity of supply	43.8	31.3	10.4	12.5	2.1
Affordability/price	50.0	2.1	8.3	6.3	8.3
Quality	77.1	14.6	4.2	0	4.2
Non-uniformity in quality batch	60.4	25.0	8.3	2.1	4.2
Physical contaminants (plastic/glass/metal etc.)	70.8	4.2	8.3	6.3	10.4
Weeds/pathogens	58.3	18.8	8.3	6.3	8.3
Low crop response	72.9	10.4	8.3	4.2	4.2
Lack of knowledge/ awareness	45.8	20.8	16.7	6.3	10.4
Odor	35.4	14.6	18.8	2.1	29.2
High labor requirements	18.8	12.5	33.3	14.6	20.8
Low nutrient values	68.8	14.6	14.6	2.1	0
No Certification	77.1	6.3	14.6	0	2.1

- **Factors affecting market demand for BEST-Comp**

Farming in Batticaloa district is subject to seasonal rainfall. This implies that there is seasonal demand for compost and sales amounts will fluctuate throughout the year. Historical sales data of the four compost plants and average rainfall data for last five years clearly indicate that there is a gradual drop in sales during the month of March to July when there is less rainfall in Batticaloa. When the rain starts in September, demand for compost increases and starts to decline again when rain gets heavier (reaching 500 ml and above). According to this pattern, the greatest demand for compost is from July to March; with lower demands from April to June.

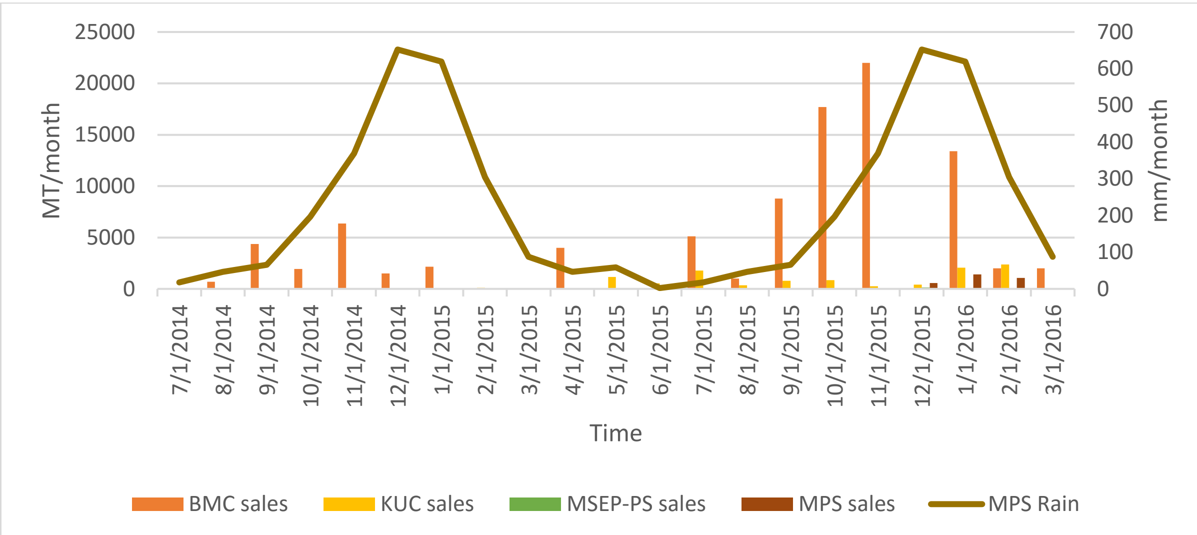

Figure 16: Correlation between compost sales and rainfall in Batticaloa

According to this seasonal demand, the production capacity of the four compost plants may need to be adjusted. Since storing compost for long periods of time can kill the microorganisms, it is important that the compost is produced in a manner that maintains and ensure its quality. According to the production data, all the compost plants with the exception of the BMC compost plant were unable to produce compost in large quantities in rainy season. BMC plant has the largest covered compost processing area among all, therefore they are able to keep a large number of matured piles indoor protecting them from rain.

- **Market size estimation**

Based on data from the Department of Agrarian Development in Batticaloa, the minimum recommended quantity of compost needed for paddy farming is 50kg per acre and for other field crops a 1:4 compost to urea ratio application is required. This suggest that there will be 406 MT of estimated compost demand per year if all farmers are encouraged to use the minimum compost requirement, based on 8138 acres of paddy farming. Similarly, there are 8447 acres of coconut and other crops which will demand at the minimum 422 MT of compost; and for vegetable and fruits cultivation, a minimum of 22 MT per year of compost. As a result, the total minimum compost market in the four localities would approximately be 1,256 MT per year. Since these estimates are based on the minimum compost requirements, actual compost usage could be higher for different crops. Thus, in the long run, demand may be higher than the baseline quantities estimated here. However, accounting for seasonal farming, compost demand will not be linear.

Table 12: Minimum market size for compost in four localities

Scale of business	Crop type		
	Paddy	Coconut, cashew and other crops	Vegetable and fruits
Micro Small Medium Large	8138 Acres @ 50 kg **Min 406MT**	8447 Acres @50Kg **Min 422 MT**	441 Acres @50 Kg **Min 22 MT**

3.2.2 Market competition

Compost generated in the four compost plants are uniquely branded as "BEST-COMP". Best-Comp is mainly sold to customers through the Agrarian Development Centers (ADC) in the locality. There were 88 MT of Best-Comp sold in year 2015 according to available sales data of each plant with an average of 7.33 MT per month. BMC plant had the highest proportion (84%) of Best comp compost sales with selling 74 MT in year 2015, followed by the KUC (12.2%) with 10 MT. The other two plants collectively claimed only 4% of the total annual sales. Low sales proposition of MPPS and MSEP is justifiable as full operations started later than the other two plants

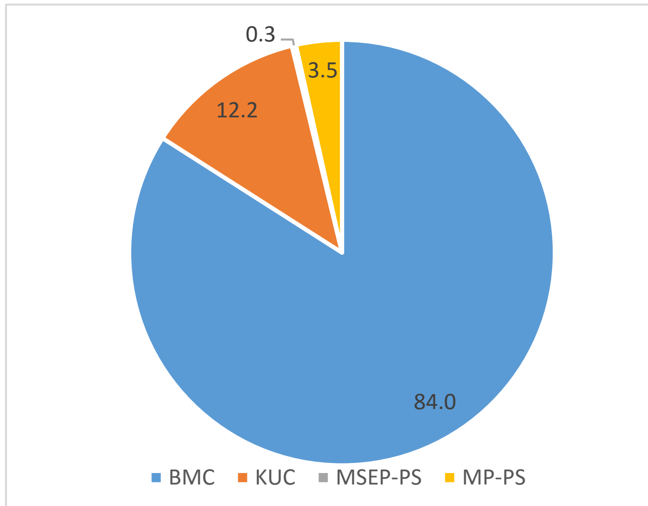

Figure 17: Percentage distribution of Best Comp sales in 2015

There are 40 small, medium and major scale private compost producers in Batticaloa district, collectively manufacturing averagely 263.5 MT of compost per year. Assuming they sell the full amount in a year, they approximately represent 350 MT of compost coming into the Batticaloa market annually. Since Best-Comp claims 88 MT from this total sales, this represents 25% of the market share which is second only to major compost manufacturers like ARAFA, CMP and Kanishka. There are large-scale private compost producers like ARAFA, CMP and Kanishka which are great competitors in the Batticaloa market. There are also emerging medium and small-scale producers producing generic compost using their farm and animal waste. Therefore, Best-Comp faces some strong competition given the economies of scale of ARAFA, CMP, etc. and the livestock waste-based compost that farmers are familiar with. The results rather show that a good strategy would be to reduce the price of the product and implement a penetrative pricing strategy (a lower market price than the prevailing competitive market price) to increase adoption rates. Strong awareness programs coupled with promotional initiatives such as testing with free samples will also be important to further increase market demand due to the fairly strong positioning of the competitors in the fertilizer market. Regular customer testing and evaluation will also be necessary to further tailor product features such as nutrient content levels, packaging and branding to consumer preferences.

3.2.3 Market segmentation

Best Comp compost is promoted as a generic MSW-based compost. Although, the compost is produced in four different plants with varying qualities, they are all marketed with the unique brand name as "Best Comp" at the same price, with same distribution channel using the same promotional campaigns. There is no any product differentiation, which does not provide sufficient value proposition to incentivize farmers to buy Best-Comp. Although, there is a large number of crops cultivated in Batticaloa by micro, small, medium and large-scale farmers, so far the product has been not promoted in these specific market segments. Since there are differences in crops, soil condition, farmers' capacity to buy, there is a need to tailor marketing strategies based on these customer segmentation.

Three major farmers' segments can be identified in the four localities. The major farming extent (in acre) in BMC and MSEP areas are paddy (cultivated in both Yala and Maha seasons). Coconut, cashew and other long-term highland crops are mainly cultivated in MPPS, MSEP and BMC area. MSEP has the highest extent of vegetable and fruit cultivation with 278 acres. Based on scale and crop type, there are twelve different potential market segments that can be penetrated using either differentiation, cost leadership or focus strategies; however, existing compost marketing strategies have not been systematic at the four compost plants. Mainly LAs sell their compost to ADCs and ADCs to farmers. A disadvantage of this approach is that the ADCs' product, price, promotion messaging is the same to farmers cultivating different crops at different scales, during different seasons. Chemical fertilizer manufacturers have identified the different nutrient requirements for different crop and this gives them a leverage in the market.

Table 13: Market segmentation based on crop and scale

		Crop type		
		Paddy	Coconut, cashew and other	Vegetable and fruits
Scale	Micro	Micro-paddy	Micro-long crop	Micro-veg
	Small	Small-paddy	Small-long crop	Small-veg
	Medium	Medium-paddy	Medium-long crop	Medium-veg
	Large	Large- paddy	Large-long crop	Large-veg
	Total extent	8138 Acres	8447 Acres	441 Acres

3.2.4 Marketing and Pricing Strategy

In reality, compost should be a nutrient-rich alternative to complement or replace the use of chemical fertilizer or other fertilizers. Farmers require an incentive to switch between fertilizer products. To achieve this, the marketing strategy needs to be a competitive market-oriented one rather than a process oriented one. However, there is no visible competitive strategy been implemented by the compost plants in Batticaloa. They do not sell the cheapest compost in the market nor have a significant positive claim to be different from other competitive products. The compost product is sold under the unique "Best Comp" brand name. Brand positioning is an essential element to create a loyal customer base for any product. Compost is not the first choice fertilizer product for the farmers and since there are other alternative products in the market, improving BEST-Comp brand awareness needs to be prioritized. In practice, the compost bags have the brand name; however, there are no additional promotions of the product – that is whether by the ADCs (who sell the product) or the plants themselves. When farmers were asked about the Best-Comp product, the majority of them were not aware of the brand.

Figure 18: Compost Bag of KUC plant

There are number of pricing strategy options available in marketing practice. They can be broadly be categorized as market penetration pricing (setting low price to create and capture the market), market skimming (charge high premium price targeting specific niche market) and competitive pricing (setting price similar to the competitive products in the market). Current pricing strategy is a competitive pricing strategy, where retail price of all four plants are set as Rs. 12/kg based on current market prices. With increased scale of production, the compost plants can benefit from economies of scale and implement a penetrative pricing strategy to capture more of the market share in view of the strong market competition they currently face.

3.2.5 Product Distribution Strategy

Marketing channels are critically important elements in marketing mix and it represents the strategies adopted to determine the “place” in marketing. According to the current marketing strategy adopted by the respective LAs, they heavily depend on the agrarian development centers in Batticaloa as their compost distribution hub. Since ADCs are government-owned fertilizer sellers, the LAs have an agreement with them to sell Best-Comp. There are 17 ADCs in the Batticaloa district and they place orders to compost plants depending on the estimated planned cultivation in the given season. ADCs receive compost from all four plants at a rate of Rs. 8/Kg. ADCs sell Best-Comp at a retail price of Rs. 12/Kg.

A high reliance on the ADCs puts the compost plants at a risk especially in view of the fact that the ADCs also promote other compost brands (private sector) which are clear competitors. This is because although the ADCs have an agreement with the LAs, they are not restricted to only selling Best-Comp. As a result, they also purchase compost from private sector producers and resell to farmers when there is high demand. Owing to the price similarity between Best-Comp and other brands, quality difference always come in to play for farmers’ purchasing decision. Since farmers are familiar with livestock-based compost, they have a natural tendency to prefer the private sector (livestock waste-based) compost.

Additionally, as there is no current ban on agro-chemical usage in Sri Lanka, farmers still prefer to use the former in comparison to compost. ADCs are still selling agro-chemicals at government subsidized price. The Agricultural Department’s DOA officers have the mandate to advise farmers on which fertilizer products to be use. With the noted higher quality of compost products from competitors, the DOAs are left to promote competitor products more than Best-Comp. This finding suggests two key needs to be addressed by the LAs: a) improvement of compost quality; b) identification of private sector entities (agricultural input suppliers or farming associations) as potential distributors. The LAs also need to consider the option of directly supplying bulk loads to farmers with free or at least subsidized transportation to increase demand. An additional consideration is the creation and promotion of a hotline number for compost orders and feedback from farmers. This has several benefits: a) it creates a direct link between the compost plants and the farmers; b) it can inform the production of the plant to adequately meet market demand.

3.2.6 Conclusions

The results of the market assessment point to the following key issues that need to be addressed:

1. The majority of farmers noted the quality of the compost produced by the plants in this study (BEST-Comp) was sub-par. They did not have confidence that the use of BEST- Comp would result in improved crop yield. Additionally, most farmers agreed that the low nutrient levels and physical contaminants of the compost product limited their use of the compost product.
2. Price was another significant factor influencing farmers' purchasing decision of Best-Comp. The farmers noted that the current price of compost (Rs. 8/kg – wholesale price; Rs. 12/kg – retail price) was higher than they would like to pay and preferred to pay Rs.6 -7 per kg, which is lower than the current wholesale price being offered by the compost plants. This is an important finding that the compost plants have to take into consideration for their market expansion strategies. Compost plants can benefit from economies of scale from increased production which can allow them to reduce the compost price.
3. Best-Comp faces some strong competition large-scale compost producers, like ARAFA, CMP, etc. and livestock waste-based compost producers. The results show that a good strategy would be to implement a penetrative pricing strategy (a lower market price than the prevailing competitive market price) to increase adoption rates. Strong awareness programs coupled with promotional initiatives such as testing with free samples will also be important to further increase market demand due to the fairly strong positioning of the competitors in the fertilizer market. Regular customer testing and evaluation will also be necessary to further tailor product features such as nutrient content levels, packaging and branding to consumer preferences.
4. A high reliance on the ADCs puts the compost plants at a risk especially in view of the fact that the ADCs also promote other compost brands (private sector) which are clear competitors. The LAs need to consider the option of directly supplying bulk loads to farmers with free or at least subsidized transportation to increase demand. Additionally, consideration of private sector entities (agricultural input suppliers or farming associations) as potential distributors is imperative. An additional consideration is the creation and promotion of a hotline number for compost orders and feedback from farmers. This has several benefits: a) it creates a direct link between the compost plants and the farmers; b) it can inform the production of the plant to adequately meet market demand.

3.3 Financial and Business Strategy Assessment

A financial analysis was conducted for all the compost plants in the study to understand the current parameters driving their financial viability. A cost-benefit analysis was conducted and the results are presented in this section for all plants, outlining the cost structure, revenue and cost recovery, current operating level and stocks, break-even analysis and recommendations.

3.3.1 Cost structure

At present, all the local authorities incur costs on waste collection, compost processing, waste disposal and for the solid waste management unit. The estimated annual cost on waste collection for BMC, KUC, MPPS and MSEP plants is: Rs.77.8mn, Rs.26.4mn, Rs.12.3mn and Rs.33.4mn, respectively. The cost of waste collection accounts for the majority of the total cost (BMC = 90%, KUC = 73%, MPPS = 67%, MPES = 89%), while a significantly small percentage for all the plants as illustrated in Table 14. Other constituting costs though marginal include: cost for disposing waste which cannot be composted and for solid waste management unit. In all of the 4 cases, initial investments were made by the EU through the SDDP and the Local Authority for the construction of the compost plant[6]. The above noted costs are estimated based on the plant capacities.

Actual costs were observed for all the plants over several months. It was noted that the observed actual costs were relatively lower than the estimated figures. According to the sample data, the monthly average costs for the BMC, KUC, MPPS and MSEP plants were Rs. 171,824, Rs. 120,078, Rs. 198,642 and Rs. 134,983, respectively. The standard deviation of the monthly average stood at 72%, 33%, 22% and 34% for the BMC, KUC, MPPS, and MSEP plants, relatively; indicating a very high volatility in monthly costs with the exception of the MPPS plant. Given the high volatility in monthly costs, the reliability of the 'actual costs' remain questionable. In this regard, unless otherwise noted, the analysis used the estimated cost figures (which are higher).

3.3.2 Revenue and cost recovery

In terms of revenue generation, the compost (Best-Comp) produced is sold in retail and bulk quantities. The retail price charged is Rs. 12/kg whereas the bulk price per kg is Rs.8/. Sales revenue recorded for the plants are as follows: BMC = Rs.0.88 million over 21months; KUC = 11 tons over 13 months; MPPS = 3 tons of compost for 3 months; and MSEP = 0.1 tons of compost for 4 months. Accordingly the average sales revenue per month is: Rs.42,105 for BMC; Rs.8,244 for KUC; Rs.10,183 for MPPS and Rs.7,130 for MSEP. The estimated annual revenue can be compared with the annual costs to identify how much of the costs can be recovered from the current income level. As Table 16 shows a greater percentage of the costs goes to waste collection and significantly lower percentage for compost production.

Waste collection costs are considered as an unavoidable cost to the local authority, as it would collect the waste regardless of whether a compost plant exists in the locality or not. Thus, the cost of waste collection is not included in the analysis. Additionally, as waste disposal costs for uncomposted waste and cost of operation of solid waste management unit are not directly related to the operation of compost plant, these costs are also not included in the 'cost recovery' calculations.

[6]Related depreciation cost are included under the compost processing cost using an average useful life of 10 years for BMC, MPPS and MSEP; and 5 years for KUC.

Table 14: Cost structure of Compost Plants

	Batticaloa Municipal Council (BMC)			Kattankudy Urban Council (KUC)			Manmunai Pattu Pradeshiya Sabha (MPPS)			Manmunai South and Eruvil Pattu (MSEP)		
Description	**Estimated Annual Cost (Rs)**	**Estimated Total Annual Cost (Rs)**	**%**	**Estimated Annual Cost (Rs)**	**Estimated Annual Cost (Rs)**	**%**	**Estimated Annual Cost (Rs)**	**Estimated Annual Cost (Rs)**	**%**	**Estimated Annual Cost (Rs)**	**Estimated Annual Cost (Rs)**	**%**
Waste collection		77,758,500	89.9		26,448,000	73		12,304,000	67		33,394,000	88.5
Compost processing :												
- Waste Processing	4,637,000			5,036,000			5,238,000			3,496,400		
- Depreciation-10%	1,902,000	6,539,000	7.6	1,690,000	6,726,000	18	690,000	5,928,000	32	770,000	4,266,400	11.3
Waste disposal		2,052,000	2.4		2,790,000	8		-	0		-	0.0
Solid Waste Management Unit		179,000	0.2		410,000	1		110,000	1		85,000	0.2
Total		**86,528,500**	100		**36,374,000**	100		**18,342,000**	100		**37,745,400**	100

Table 15: Observed actual costs

Description	BMC	KUC	MPPS	MSEP
Sample period (Months)	8	9	8	9
Total Cost observed (Rs.)	1,374,589	1,080,700	1,589,137	1,214,850
Monthly average (Rs.)	171,824	120,078	198,642	134,983
Standard deviation per month (Rs.)	123,134	40,055	43,319	46,120
Annualized Cost (Rs.)	2,061,883	1,440,933	2,383,705	1,619,800

Table 16: Input-Output Volumes and Revenue

		BMC			KUC			MPPS			MSEP		
Description	**UoM**	**For 21 months**	**Average per month**	**Estimated values per annum**	**For 17 months**	**Average per month**	**Estimated values per annum**	**For 20 months**	**Average per month**	**Estimated values per annum**	**For 20 months**	**Average per month**	**Estimated values per annum**
Input-Segregated Waste	Loads	1,148	54.7	656	1,119	65.8	789.5	481	24.1	288.6	360	18.0	216.0
Input-Segregated Waste	Ton	1,378	65.6	787	1,342	79.0	947.4	577	28.9	346.3	432	21.6	259.2
Output-Compost	Ton	104	5.0	59	27	1.9	22.9	7	1.4	16.5	5.6	1.1	13.3
Sales-Compost	Ton	93	4.4	53	11	0.8	9.9	3	1.0	12.2	0.3	0.71	8.6
Sales Revenue	Rs.		42,105.3	**505,264**		8,244	**98,926**		10,183	**122,200**		7,130	**85,558**

Table 17: Cost Recovery

	BMC				KUC				MPPS				MSEP			
	With Depreciation		**Excluding Depreciation**		**With Depreciation**		**Excluding Depreciation**		**With Depreciation**		**Excluding Depreciation**		**With Depreciation**		**Excluding Depreciation**	
Description	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**
Annual Operating Cost	6,539,000	100	4,637,000	100	6,726,000	100	5,036,000	100	5,928,000	100	5,238,000	100	4,266,400	100	3,496,400	100
Est. annual revenue	(505,264)	8	(505,264)	11	(98,926)	1	(98,926)	2	(122,200)	2	(122,200)	2	(85,558)	2	(85,558)	2
Annual loss	**6,033,736**		**4,131,736**		**6,627,074**		**4,937,074**		5,805,800		5,115,800		4,180,842		3,410,842	
UNOPS Support	(2,400,000)	37	(2,400,000)	52	(1,950,000)	29	(1,950,000)	39	(2,400,000)	40	(2,400,000)	46	(2,400,000)	56	(2,400,000)	69
Unrecovered Op. Cost	3,633,736	56	1,731,736	37	4,677,074	70	2,987,074	59	3,405,800	57	2,715,800	52	1,780,842	42	1,010,842	29

Accordingly, Table 17 illustrates the cost recovery of all the compost plants. The current revenue earned by the plants is sufficient to cover only 2% of the annual operating costs excluding the depreciation for the KUC, MPPS and MSEP plants, while BMC is able to cover 11%. The contribution of UNOPS towards the operational costs of the compost plants stands at 52%, 39%, 40% and 56% for BMC, KUC, MPPS and MSEP, respectively. The remaining balance of the operating cost which is uncovered, ranges between 37 – 59% (KUC have the highest balance) and for which the LA has to bear as a cost.

3.3.3 Current operating level and stocks

The design capacity of the plants are 12 tons of segregated waste per day for BMC and KUC; 7 tons for MPPS and MSEP. With a 6-day per week operational schedule for all the plants, if we assume that they all operate for 52 weeks per year, the design capacity can be calculated to be 3,744 tons per annum for the BMC and KUC plants; 2,184 tons per annum for the MPPS and MSEP plants. Using the current Input-Output ratio of 5:1, the design capacity in terms of the compost produced is 62 tons/month for BMC, 94 tons/month for KUC, and 36 tons/month for both MPPS and MSEP as shown in table 18. When the actual input and output per month is compared with the design capacity per month, current operating level or the efficiency level can be calculated as shown in table 18.

Accordingly, the input i.e. segregated waste processed by the plant at present is 21%, 25%, 16% and 12% of the design capacity for inputs for the BMC, KUC, MPPS and MSEP plants, respectively. The results show that in general, the efficiency levels of all the plants are significantly low, with the MSEP plant having the lowest level. Additionally, the current compost production is only 8%, 3%, 4% and 3% of the design capacity for output for the BMC, KUC, MPPS and MSEP plants, respectively. The difference between the efficiency level calculated for input and the efficiency level calculated for output is mainly due to the work in progress (WIP) stocks.

Current stock levels of the plants are calculated and presented in Table 19. It can be observed that the expected compost productions under the current level of inputs are 13.1, 15.8, 5.8 and 4.3 tons for the BMC, KUC, MPPS and MSEP plants, respectively. However, the actual production is significantly lower for all the plants. The difference is attributable to the WIP stocks i.e. the waste being processed in to compost. WIP stocks can either be expressed in terms of the input waste or output compost. Table 19 shows the WIP stocks in terms of output compost i.e. the equivalent units of compost that can be produced from WIP waste stocks. A notable difference is also noted between average monthly sales and production (unsold finished goods stock); where the former is significantly lower than the latter and KUC having the greatest difference.

Table 18: Current efficiency level

Description	UoM	BMC Per Month	KUC Per Month	MPPS Per Month	MSEP Per Month
Design Capacity					
Input -Segregated Waste	Ton	312	312	182	182
Output -Compost (20% of Input)	Ton	62	62	36	36
Actual Operation					
Actual Input-Segregated Waste	Ton	66	79	29	22
Actual output –Compost	Ton	5	2	1	1
Efficiency level					
Input (Actual Input/Design Input)	%	21	25	16	12
Output (Actual output/Design output)	%	8	3	4	3

Table 19: Current stocks level

	BMC		KUC		MPPS		MSEP	
Current Operating Volumes	**Per Month (Tons)**	**%**	**Per Month (Tons)**	**%**	**Per Month (Tons)**	**%**	**Per Month (Tons)**	**%**
Average Input -Segregated Waste	65.6		79.0		28.9		21.6	
Expected output-Compost (20% of Input) (A)	13.1	**100%**	15.8	100	5.8	100	4.3	100
Actual Average Production per month (B)	5.0		1.9		1.4		1.1	
WIP stock-Compost equivalent (A-B)	8.2	62%	13.9	88	4.4	76	3.2	74
Actual Average Sales per month (C)	4.4	34%	0.8	5	1.0	18	0.7	17
Finished Goods Stock (B-C)	0.5	4%	1.1	7	0.4	6	0.4	9

3.3.4 Break Even Point and Financial Profit

- **Break-Even Point**

Break Even Point (BEP) states how many tons of compost is needed to sold to recover the operational costs. In other words, it is the point where the plant generates neither profit nor loss. This can be calculated by dividing the annual operational cost of the plant by contribution earned per ton of compost.

$$\text{BEP (Tons)} = \frac{\text{Operational Costs}}{\text{Contribution earned per ton}}$$

Contribution earned per ton of compost is the sales revenue per ton minus the variable cost per ton. Accordingly the contribution per ton of compost is Rs. 9,600 as estimated in Table 20. Current fixed costs primarily attributable to waste collection, compost processing, waste disposal and solid waste management unit as noted above. It is important to note that the cost of waste collection is an unavoidable cost for the local authority and does not occur solely as a result of the composting plant. Thus, it is included in the breakeven analysis, as is the waste disposal and solid waste management unit (reasoning provided previously). Accordingly, the BEP is calculated to evaluate how many tons of compost is needed to be produced and sold in order to cover the annual operational costs attributable to compost processing, i.e. Rs. 6.5mn for the BMC plant, for example. When this cost is divided by the contribution per ton of Rs. 9,600/=, the BEP is calculated to be 681 tons for BMC plant. The BEP stands at 701, 618 and 444 tons per annum for the KUC, MPPS and MSEP plants, respectively. Given that the input-output ratio for compost is 5:1, the BMC plant needs to process 3,406 tons of segregated waste to produce the BEP quantity of compost. With a current design capacity of the plant at 12 tons of segregated waste per day, if the plants is operated for 6 days per week and 52 weeks per year, the design capacity per annum is calculated to be 3,744 tons. Thus, the calculated BEP of segregated waste is 91% of the design capacity; implying that the plant needs to operate above 91% to make financial profits. Based on this analogy, the calculated BEP of segregated waste is 94%, 141%[7] and 102% of the design capacity for the KUC, MPPS and MSEP plants, respectively.

The BEP is further calculated under the scenarios of fixed costs excluding depreciation and annualized cost on observed data presented in Table 22. It can be observed that the BMC plant can reach the breakeven point by operating at 65% efficiency level when the depreciation is excluded. With the observed actual operating cost of the plant (based on collected data), operational cost were at Rs. 2 million per annum. This cost can be recovered, if the plant sells 215 tons per annum i.e. operating at 29% of the design capacity. The KUC and MSEP plants can reach the breakeven point by operating at 70% and 83% efficiency level when the depreciation is excluded, respectively. The MPPS plant however cannot reach the breakeven point even when depreciation is excluded. The design capacity of the MPPS plant is currently at 2,148 tons of segregated waste. The plant however will need to increase its capacity (the current capacity is too small to reach breakeven) to be able to process 3,088 tons of segregated waste (to produce and sell 546 tons of compost) in order to break-even if depreciation is considered. Without depreciation, the design capacity is lower at 2,728 tons of segregated waste.

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[7] The calculated BEP of segregated waste is 141% of the design capacity so that the plant cannot reach the BEP. As a result the plant is not able to cover its annual fixed costs thus it would record a financial loss every year.

Table 20: Contribution per ton of compost

Description	Retail sales	Bulk sales	Total (Rs.)
Selling price (Rs. Per kg)	12	8	
Variable cost (Rs. Per kg)	(0.4)	(0.4)	
Contribution (Rs. per kg)	11.6	7.6	
Sales Mix %	50%	50%	
Contribution per kg			9.60
Contribution per Ton			9,600.00

Table 21: Break Even Point

	BMC		KUC		MPPS		MSEP	
Description	Tons	%	Tons	%	Tons	%	Tons	%
Break Even Point-Compost	681		701		618		444	
Break Even Point -Segregated waste	3,406		3,503		3,088		2,222	
Design Capacity- Segregated waste	3,744		3,744		2,184		2,184	
BEP as a % of design capacity		91%		94%		141%		102%

Table 22: Sensitivity of Break Even Point

	BMC		KUC		MPPS		MSEP	
Description	Excluding Depreciation	Annualized observed actual cost	Excluding Depreciation	Annualized observed actual cost	Excluding Depreciation	Annualized observed actual cost	Excluding Depreciation	Annualized observed actual cost
Annual Fixed Cost (Rs.)	4,637,000	2,061,883	5,036,000	1,440,933	5,238,000	5,238,000	3,496,400	1,619,800
Break Even Point-Compost	483	215	525	150	546	546	364	169
Break Even Point -Segregated waste	2,415	1,074	2,623	750	2,728	2,728	1,821	844
Design Capacity- Segregated waste	3,744	3,744	3,744	3,744	2,184	2,184	2,184	2,184
BEP as a % of design capacity	65%	29%	70%	20%	125%	125%	83%	39%

Using the annualized cost on observed data, it is observed that for the KUC, MPPS and MSEP plants, the operational costs can be recovered if the plants sell 150 tons/annum (i.e. operating at 20% of the design capacity); 248 ton/annum (i.e. operating at 57% of the design capacity); and 169 tons/annum (i.e. operating at 39% of the design capacity), respectively.

➢ Financial Profit

a) With estimated costs

In terms of financial profits, we see from table 23 that if the BMC plant operates under 90% efficiency level, the financial loss (inclusive of depreciation) is estimated at Rs. 0.07 mn. The loss is calculated under the assumption that fixed operational cost remain constant despite the increase from current efficiency level of 21% to 90% efficiency level. Financial performance of the plant under different operating levels are shown in Table 24. This analysis assumes that the opening and closing stocks are equal. Additionally, it is assumed that the annual fixed operating costs remain constant despite the changes in operating level. Under the 50% operating level, the contribution earned by the plant is sufficient to recover only 55% of the operating cost (assuming no external support is provided, i.e. the EU through the SDDP ends its financial support to cover a % of the operational costs). At present, the plant operates at 21% efficiency level in terms of input, however actual sales is as low as 4.4 tons per month and 53 tons per annum due to WIP and finished goods stocks. When current sales level is compared with the sales target under 50% operating level, it can be noted that current demand needs to increase 7 times (374/53) to achieve the target level of 50%. Additionally, the current input level of segregated waste is 787 tons per annum. When this is compared with the input required for 50% operating level, segregated waste input needs to double (1872/787) to achieve the 50% target.

At a 90% operation efficiency level and excluding depreciation, all the plants record a positive profit level with the exception of the MPPS plant which records a loss of Rs. 1.46 million/annum. Under similar assumptions, the KUC plant the contribution earned by the plant under the 50% operating level is sufficient to recover only 53% of the operating cost. At present the plant operates at 25% efficiency level in terms input, however actual sales are as low as 0.8 tons per month and 9.9 tons per annum due to WIP and finished goods stocks. When current sales level is compared with a sales target of 50% operating level, it can be noted that current demand needs to increase by 38 times (374/9.9) to achieve a target level of 50%. Additionally, the current input level of segregated waste is 789.5 tons per annum. When this is compared with the input required for 50% operating level, segregated waste input has to increase 2.4 times (1872/789.5) to achieve the 50% target. Given the rise in the demand and input required to operate at 50% level, it is likely that the plant will operate below the 50% level. Aggressive marketing strategies and reduced operational costs can help the plant increase its production capacity to reach financial viability at 75% operating level. These findings are also similar for the MSSP and MSEP plants.

b) With observed actual costs

Tables 25 and 26 present the results for the financial performance of the compost plants using annualized observed actual cost. It is important to note that these figures are significantly lower than the estimated cost figures and had high standard deviations. An improvement in the profit levels are noted for all the compost plants under increasing efficiency levels. This result is particularly important for the MPPS plant which posted negative profit levels even under 90% efficiency. This is because although a high volatility in the monthly costs was recorded for the other plants, a standard deviation of 22% of the monthly average costs for the MPPS plant suggests modest volatility in monthly costs, making the ‘actual costs’ for the MPPS plant more credible. It is noted that at a 75% efficiency level, the MPS plant posts a positive profit with or without the inclusion of depreciation and excluding any external support.

Table 23: Financial Profit at 90% efficiency level

Description	BMC			KUC			MPPS			MSEP		
	Tons	Profit after depr. (Rs.)	Profit before depr. (Rs.)	Tons	Profit after depr. (Rs.)	Profit before depr. (Rs.)	Tons	Profit after depr. (Rs.)	Profit before depr. (Rs.)	Tons	Profit after depr. (Rs.)	Profit before depr. (Rs.)
Design Capacity-Segregated waste	3,744			3,744			2,184			2,184		
90 % efficiency level-Segregated waste	3,370			3,370			1,966			1,966		
Compost produced @ 90% efficiency	674			674			393			393		
Contribution earned @ 90% efficiency		6,469,632	6,469,632		6,469,632	6,469,632		3,773,952	3,773,952		3,773,952	3,773,952
Less: Annual fixed cost		(6,539,000)	(4,637,000)		(6,726,000)	(5,036,000)		(5,928,000)	(5,238,000)		(4,266,400)	(3,496,400)
Profit/(Loss)		**(69,368)**	**1,832,632**		**(256,368)**	**1,433,632**		**(2,154,048)**	**(1,464,048)**		**(492,448)**	**277,552**

Table 24: Sensitivity analysis of plant financial performance

Description	BMC			KUC			MPPS			MSEP		
	Operating/Efficiency Level			Operating/Efficiency Level			Operating/Efficiency Level			Operating/Efficiency Level		
	50%	**75%**	**100%**	**50%**	**75%**	**100%**	**50%**	**75%**	**100%**	**50%**	**75%**	**100%**
Input-Segregated Waste (Ton)	1,872	2,808	3,744	1,872	2,808	3,744	1,092	1,638	2,184	1,092	1,638	2,184
Output-Compost (Ton)	374	562	749	374	562	749	218	328	437	218	328	437
Contribution earned (Rs.)	3,594,240	5,391,360	7,188,480	3,594,240	5,391,360	7,188,480	2,096,640	3,144,960	4,193,280	2,096,640	3,144,960	4,193,280
Less: Annual fixed cost (excl. dep.)(Rs.)	(4,637,000)	(4,637,000)	(4,637,000)	(5,036,000)	(5,036,000)	(5,036,000)	(5,238,000)	(5,238,000)	(5,238,000)	(3,496,400)	(3,496,400)	(3,496,400)
Profit/(Loss) before depreciation (Rs.)	**(1,042,760)**	**754,360**	**2,551,480**	**(1,441,760)**	**355,360**	**2,152,480**	(3,141,360)	(2,093,040)	(1,044,720)	(1,399,760)	(351,440)	696,880
Less: Depreciation	(1,902,000)	(1,902,000)	(1,902,000)	1,690,000)	(1,690,000)	(1,690,000)	(690,000)	(690,000)	(690,000)	(770,000)	(770,000)	(770,000)
Profit/(Loss) after depreciation (Rs.)	**(2,944,760)**	**(1,147,640)**	**649,480**	**(3,131,760)**	**(1,334,640)**	**462,480**	(3,831,360)	(2,783,040)	(1,734,720)	(2,169,760)	(1,121,440)	(73,120)

Table 25: Plant financial performance using observed actual cost for BMC and KUC plants

Description	BMC				KUC			
	Operating/Efficiency Level				Operating/Efficiency Level			
	25%	**50%**	**75%**	**100%**	**25%**	**50%**	**75%**	**100%**
Input-Segregated Waste (Ton)	936	1,872	2,808	3,744	936	1,872	2,808	3,744
Output-Compost (Ton)	187	374	562	749	187	374	562	749
Contribution earned (Rs.)	1,797,120	3,594,240	,391,360	7,188,480	1,797,120	3,594,240	5,391,360	7,188,480
Less: Annual fixed cost (excl. dep.)(Rs.)	(2,061,883)	(2,061,883)	(2,061,883)	(2,061,883)	(1,440,933)	(1,440,933)	(1,440,933)	(1,440,933)
Profit/(Loss) before depreciation (Rs.)	(264,763)	1,532,357	3,329,477	5,126,597	**356,187**	**2,153,307**	**3,950,427**	**5,747,547**
Less: Depreciation	(1,902,000)	(1,902,000)	(1,902,000)	(1,902,000)	(1,690,000)	(1,690,000)	(1,690,000)	(1,690,000)
Profit/(Loss) after depreciation (Rs.)	(2,166,763)	(369,643)	1,427,477	3,224,597	**(1,333,813)**	**463,307**	**2,260,427**	**4,057,547**

Table 26: Plant financial performance using observed actual cost for MPPS and MSEP plants

Description	MPPS				MSEP			
	Operating/Efficiency Level				Operating/Efficiency Level			
	25%	**50%**	**75%**	**100%**	**25%**	**50%**	**75%**	**100%**
Input-Segregated Waste (Ton)	546	1,092	1,638	2,184	546	1,092	1,638	2,184
Output-Compost (Ton)	109	218	328	437	109	218	328	437
Contribution earned (Rs.)	1,048,320	2,096,640	3,144,960	4,193,280	1,048,320	2,096,640	3,144,960	4,193,280
Less: Annual fixed cost (excl. dep.)(Rs.)	(2,383,705)	2,383,705)	(2,383,705)	(2,383,705)	(1,619,800)	(1,619,800)	1,619,800)	(1,619,800)
Profit/(Loss) before depreciation (Rs.)	(1,335,385)	(287,065)	761,255	1,809,575	**(571,480)**	**476,840**	**1,525,160**	**2,573,480**
Less: Depreciation	(690,000)	(690,000)	(690,000)	(690,000)	(770,000)	(770,000)	(770,000)	(770,000)
Profit/(Loss) after depreciation (Rs.)	(2,025,385)	(977,065)	71,255	1,119,575	**1,341,480)**	**(293,160)**	**755,160**	**1,803,480**

3.3.5 Conclusions

The financial assessment provided the following key findings:

- Although the compost processing costs constitute a significantly small percentage of the total cost to the LAs, the current revenue earned by the plants is insufficient to cover the operational cost for compost plants (and covers only 2% of the annual operating costs excluding the depreciation for the KUC, MPPS and MSEP plants, while BMC is able to cover only 11%). The contribution of UNOPS towards the operational costs of the compost plants stands at 52%, 39%, 40% and 56% for BMC, KUC, MPPS and MSEP, respectively. The remaining balance of the operating cost which is uncovered, ranges between 37 – 59% (KUC have the highest balance) and for which the LA has to bear as a cost.
- The results show that in general, the efficiency levels of all the plants are significantly low, with the MSEP plant having the lowest level. Additionally, the current compost production is only 8%, 3%, 4% and 3% of the design capacity for output for the BMC, KUC, MPPS and MSEP plants, respectively. The difference between the efficiency level calculated for input and the efficiency level calculated for output is mainly due to the work in progress (WIP) stocks.
- A notable difference also observed is between the average monthly sales and production (unsold finished goods stock); where the former is significantly lower than the latter and KUC having the greatest difference.
- The calculated BEP of segregated waste is 91%, 94%, 141%[8] and 102% of the design capacity for the BMC, KUC, MPPS and MSEP plants, respectively. At a 90% operation efficiency level and excluding depreciation, all the plants record a positive profit level with the exception of the MPPS plant which records a loss of Rs. 1.46 million/annum. The financial sustainability of the MPPS plant is thus highly questionable as the plant needs to operate at a very high level of operating level i.e. 141% of design capacity in order reach the break-even point where the current operating level is only at 16%.
- The BEP was further calculated under the scenarios of fixed costs excluding depreciation and annualized cost on observed data presented in Table 22. It can be observed that the BMC, KUC and MSEP plants can reach the breakeven point by operating at 65%, 70% and 83% efficiency level when the depreciation is excluded, respectively. The MPPS plant however cannot reach the breakeven point even when depreciation is excluded.
- Using the annualized cost on observed data[9], an improvement in the profit levels was observed for all the compost plants under increasing efficiency levels. This result is particularly important for the MPPS plant which posted negative profit levels even under 90% efficiency. This is because although a high volatility in the monthly costs was recorded for the other plants, a standard deviation of 22% of the monthly average costs for the MPPS plant suggests modest volatility in monthly costs, making the ‘actual costs’ for the MPPS plant more credible. It is noted that at a 75% efficiency level, the MPS plant posts a positive profit with or without the inclusion of depreciation and excluding any external support.

[8] The calculated BEP of segregated waste is 141% of the design capacity so that the plant cannot reach the BEP. As a result the plant is not able to cover its annual fixed costs thus it would record a financial loss every year.
[9] It is important to note that these figures are significantly lower than the estimated cost figures and had high standard deviations, thus credibility of data questionable.

4. Technical Needs Assessment and Capacity Development

4.1 Overview

The production, marketing and utilization of MSW-based compost as an organic fertilizer is a scientific knowledge-centric process that requires the application of specialized knowledge, skills, and experiences throughout the compost value chain. Therefore, all the stakeholders in the production and marketing process need to be empowered with the scientific principles of composting process in a way that they can understand and continually apply that knowledge. Following the assessment of the sub-optimalities in the operational system of the compost plants, it is important to assess the technical and capacity development needs required to improve plant performance and long-term sustainability.

Some notable issues noted with the operational system relate to: a) significant production inefficiencies; b) low product quality; c) significant market competition; d) poor marketing and pricing strategy; and e) high reliance on single avenue distributor, amongst others. Based on the results from the technical and business (market and financial) assessments of all the four compost plants established in Batticoloa district, none of them have yet met the expected production levels of high quality compost. The current pricing and marketing strategies of the plants are not very promising, where the current sales volumes are insufficient to cover the operational costs of the plants. Additionally, farmers are generally not aware of the Best-comp brand. Given that marketing of the compost is mainly supply driven by the Department of Agrarian Development (DAD) tied with the government fertilizer subsidy programme, the majority of the buyers opt to buy the compost from their respective ADCs at the time of fertilizer subsidy disbursement regardless of the brand name. It was noted that the reluctance of government extension officers in recommending Best-Comp is mainly due to the gap in the awareness of quality standards and assurance of the product. Whilst, compost producers need to be trained on product quality improvement, empowering the farmers and suppliers (ADCs) to be quality conscious of the compost they buy in a competitive market environment is also an important requirement. This is because creating awareness among end users on quality is critical for increased product demand.

Improved product quality and performance of the compost plant require well-trained workers. It was noted that although, all the compost plant workers and supervisors have gone through a series of training programs at the beginning of plant operations, there are significant differences in composting practices in the different plants. Unorthodoxies in plant operations against the recommended best practices might be a reason for the lower quality standard and production volumes of the BEST-Comp compost, which may be a challenge in the future in the given competing market environment.

4.2 Situational Analysis of Capacity Building efforts

4.2.1 Existing training orientation

The capacity building team of the UNOPS has conducted a series of training on various aspects of the composting business to the local authority (LA) staff/ personnel, LA officials (chairman, council members, commissioner, etc.), selected government officers in the district, school environmental clubs, plant supervisors and workers. The modes of training included brainstorming sessions, classroom lecturers, workshops, meetings, practical sessions, and exposure visits. The training programmes conducted in the past were mainly focused on the following broad areas during the period of 2013-2016: product awareness, capacity building, skills development, technical training and improve the exposure of the stakeholders. These specifically included:

1. Basics of SWM
2. Planning of SWM – operation and preparation of plan
3. Improving waste collection services – segregation at the source, installation of the waste segregation system, tracking of waste collection vehicles
4. Operation and maintenance of SWM facilities – both the compost facility and landfill sites
5. Training on SWM by-laws
6. Labor training- compost facility laborers, collection laborers, health laborers, occupational health and safety
7. Community awareness and mobilization- training on community awareness for LA staff, youth leadership development programme, awareness on SWM for school children through school environmental clubs
8. Business development and marketing of compost and recyclables
9. Sharing in-country experiences through exposure visits (visit to the SWM facilities at Nuwaraleya, Matale and Thirukkovil)

4.2.2 Identified training gaps

The research team with the assistance of the capacity building team of the UNOPS – Batticaloa, have identified a number of avenues which require further training and capacity development interventions. These include the following:

1. UNOPS has provided technical and operational advice to the LAs and have supported capacity development. Given the identified operational gaps, there is a tendency that a vacuum in the provision of this support will be created at the district level after the withdrawal of UNOPS from the project. It is recommended to formulate an apex body consisting of representatives of SWM units of relevant councils, Provincial/District level officials of Department of Agriculture, Department of Agricultural Extension, Department of Agrarian Development (DAD), Divisional Officers (DOs) of DAD, representatives of Farmer Organizations (FOs) and other interested parties. The apex body would be a forum to share resources, knowledge and lessons learned, discuss common problems/ challenges and formulate a seasonal production plan to manage the compost demand at the district levels, plan and implement future development initiatives, and high-tech solutions, and develop strategies for market expansion, value additions and product diversification. Additionally, the apex body could serve to support the implementation of the technical and business recommendations.

2. Gaps in the updated technological changes and best practices: The LA personnel have already received significant training on different aspects of integrated waste management; and operation and management of SWM facilities. However, with the development of new technologies and best practices that have the potential to improve plant performance, the provision of skill enhancement training on related subjects would further strengthen their capabilities. Additionally, training on new technologies such as development of faecal sludge-based co-compost *(Fortifer)* is imperative.

3. Labor allocation and keeping workers' motivation high: It was reported and observed that the laborers working in the compost facility are less advantaged in terms of monetary incentives and timing of work hours compared to the waste collection laborers (collection laborers are able to get some additional income from the sale of recyclable waste). Therefore, it is recommended to

provide the training given to the compost facility laborers (on the operation and management of compost facility and composting process) to the waste collection workers as well and make arrangements to utilize both collection and compost facility laborers on a rotational basis. This can help reduce challenges related to labor deficit and keep worker motivation high.

4. Marketing and business development/entrepreneur skills: The knowledge and competence in market development and marketing of compost seem to be insufficient for the compost facility supervisors and other relevant officials, which are vital to develop the market linkages in the competitive environment and also to promote the compost marketing. The marketing and business development training package should include basic training on product marketing, building customer relationships and strategic partnerships, product diversification, and promotion.

5. Knowledge gap at the end users level: Private sector entities involved in the compost business have already adopted different strategies at farmer level (awareness raising, development of demonstration plots in farmers' field, providing exposure visits and educational projects to the farmers) to convince them to buy organic compost marketed by them. The gap between the lack of knowledge and sustainable compost sales can be narrowed with increased awareness among the community. Awareness and knowledge building programmes should address the importance of MSW compost as well as disadvantages of inorganic fertilizers in the given context.

6. Insufficient capacity of SWM unit established in the LAs: SWM units in the local authorities need to be strengthened by providing training and awareness on MSW compost production, skills on marketing of product and building viable enterprises. An officer(s) in the unit should be assigned with adequate capacity development who would be the responsible person for the product marketing/ promotion, communicating with potential buyers (government agencies, NGOs and the special projects) and the establishment of market linkages.

7. Lack of adequate awareness on MSW compost among stakeholder agencies and weaker linkages between MSW compost plant/production and grassroots officers: Training and awareness programmes on the MSW compost manufacturing process, quality certification and the importance/benefits of the MSW management programme to the local environment and the community should be provided to stakeholder agency officers (Department of Agriculture (DOA), Department of Agrarian Development (DAD), Coconut Cultivation Board (CCB), Sri Lanka Cashew corporation (SLCC)) and the grass root level officers (Agricultural Officers (AO), Agricultural Instructors (AI), Agricultural Research and Production Assistants (ARPA) etc.).

Although a large number of training programs have been conducted in the past, the impacts of these trainings on the capacity building were not successfully measured. This TNA aims to suggest training programs to fill specific knowledge gaps by stating the expected outcomes and measurable indicators to ensure the achievement of the expected outcomes by fulfilling the training needs. The proposed training and capacity building programmes are summarized in table 27 below.

Table 27: Summarized training need assessment

Stakeholder	Purpose/impact	Expected capacity development (Skills, Knowledge, Experience)	Current gap	Proposed training areas	Impact Indicators
Plant Supervisors	**Speed up the composting cycle; increase the production quantity and quality; increase product sales; develop compost plant as sustainable business through value additions**	1. Awareness of the windrow composting process 2. Ability to recognize green & brown elements of the waste 3. Basic math on pile composition 4. Ability to improve the quality by adding values/co-composting (*Fortifer technology)* 5. Leadership skills 6. Ability to explain compost as fertilizer 7. Produce value-added compost/ product diversification	1. Despite the training provided, supervisors tend to use their own methods and practices; and with time deviate from best practices 2. Lack of knowledge on new technologies to accelerate the production (e.g. Barkley method of composting) 3. Methods of ensuring quality of the compost product through controlling the input and the composting process.	▪ Refresher training program on best practices in Rapid MSW composting-Barkley method ▪ Training on production of value-added compost based products and co-composting ▪ Leadership training to enhance leadership skills ▪ Awareness of how to use organic fertilizer in farming; agronomic trials ▪ Training on compost marketing and maintaining customer relationship	Duration of compost cycle Production amount sales quantity Types of composts produced Customer retention rate
		8. Record keeping and certification	Lack of knowledge on technical requirements needed to obtain product certification, such as SLS 1246:2003	Training on SLS 1246-2003 Specification for Compost from Municipal Solid Waste And Agricultural Waste	Quality elements of compost (CN Ratio, Moisture, pH value…)
		9. Ability to understand compost as business	MSW composting is rapidly moving from a social responsibility to business in the context of growing competition from private sector in the area. Supervisors should understand this development the context to make the enterprise as a sustainable business model.	▪ Production planning ▪ Entrepreneurial training to make it as profitable business ▪ Strategies and incentive mechanisms to increase labor productivity, financial viability, product diversification and innovative marketing.	▪ Sales growth rate ▪ Number of new customers per year ▪ Number of retaining customers ▪ Number of new products ▪ Annual profitability
Plant workers	**Motivated and committed work force to achieve expected quantity and quality of compost production**	1. Understanding of good and bad elements in composting	Lack of knowledge on best practices and new composting methods	▪ Onsite refresher training on best practices in plant operation: dos and don'ts	▪ Duration of compost cycle Production amount Sales volume ▪ Types of composts produced ▪ Customer retention rate
		2. Ability to recognize green & brown elements of the waste	Workers forget/ignore the exact elements to be included into pile, there ratios	▪ On the job training on explaining nitrogen and carbon elements in local plants| how they should be mixed to achieve C/N Ratio	▪ Improvement in Quality elements (C/N Ratio, Moisture, pH, etc.…)

		3. Basic math on pile composition	Practical application of C: N ratios, input quantities, temperature, moisture concepts need to be taught	▪ On the job training on modern piling practices; understand the short comings, maintaining correct balance	
		4. Ability to increase the quality by adding values 5. Ability to explain compost as fertilizer	Lack of understanding on the value chain and the importance of farmers' concerns.	▪ Basic training on organic farming and integrated plant nutrient management in the given context. ▪ Role of compost in soil fertility management.	▪ Sales growth rate ▪ Number of new customers per year ▪ Number of retaining customers
		6. Produce value-added compost	Lack of knowhow on product diversification and value additions	▪ Training on product diversification, value addition and co-composting	▪ Number of new products ▪ Annual profitability
Employees at SWM unit and Sales center	**Increase compost marketing through good customer relationship / increase ability to educate farmers**	1. Personal relation/ communication skills 2. Marketing skills 3. Roles of organic fertilizer 4. Understanding of organic farming / integrated plant nutrient management	Insufficient skills on marketing and communication to convince customers and establish business linkages	▪ Training for compost sales and marketing staff on the basics of compost marketing and sales, as well as provide pertinent technical information pertaining to compost benefits, and plant and soil responses (ammunition for the compost salesperson).	▪ Rate of increase of sales ▪ Number of new customers per year ▪ Number of retaining customers ▪ Changes in the annual profitability of the plant
Farmers/ farmer representatives	**To increase farmers awareness on organic farming and integrated plant nutrient management and to be locked in with 'Best-Comp'**	1. Awareness about the benefits of organic fertilizer	Limited evidence-based awareness and practical experiences among farmers on benefits of compost use .	▪ Start few pilot projects and demonstration sites on organic farming/compost use in farming areas to share experiences and exposures ▪ Costs and benefits of compost use	▪ Number of farmers using MSW compost ▪ Increased yield ▪ Increased Best-Comp sales
		2. Ability to use right mix, right quantity	Understanding is needed on long-term effects of organic fertilizer in increasing soil fertility and productivity	▪ Training on rationing and mixing of compost for different crops in the different contexts	
		3. Brand awareness	Lack of understanding of the quality aspects of different brands and the benefits of using MSW compost	▪ Awareness campaign, exhibition, and road shows to promote and popularize "Best Comp" brand among the farmers (and other stakeholders).	
Line agencies (DOA, DAD, CCB, SLCC)	**Convert agency officers as change agents to create a demand for BEST-COMP** **Make them aware about the quality and quality certification of Best-comp**	1. Awareness about the MSW composting process 2. Knowhow on the differences of BEST-COMP and other brands 3. knowledge about the quality standards of the Best-comp	1. Low awareness about the composting process, quality and quality standards of 'Best Comp' 2. Agency officers have their own preferences and preconceptions about the quality of available compost in the market.	i.) Awareness workshop about the composting process at four plants, quality standards and certification of BEST-comp compost ii.) Field visit to compost plants to explain the process standards and quality measures are in action. iii.) Sharing the knowledge obtained from empirical studies (MSW compost vs other brands)	a. Number of DAD centers involved in Best Comp marketing b. Rate of change in Best Comp marketing by agencies c. Agency officers' testimonies (qualitative)

5. Recommendations and Conclusions

5.1 Overview

The objective of this research project is to recommend strategies for the recovery and productive reuse of municipal solid waste (MSW) of four compost plants in the Batticaloa district, with a view of ensuring the provision of sustainable waste management services by the respective local authorities (LAs). The long-term sustainability of the compost plants depend on several factors ranging efficient production processes, sound business strategies to solid institutional support. Resource recovery and reuse (RRR) for waste management (e.g. composting) are often solely viewed as social initiatives; and thus require significant external financial support. This oftentimes renders the initiatives unsustainable as the required financial mechanisms are not in place to begin with. In view of the increasingly limited public funds to support waste management infrastructure and services, it is imperative that returns on investments of RRR initiatives are positive and sustainable in the long-term.

The 4 compost plants in the Batticaloa district, under consideration in this study, generate significant benefits to communities by reducing health hazards from decreased exposure to untreated waste. The compost plants, like in many developing countries, receive significant external financial support to sustain their operational activities. It is imperative that, although the initiatives have a strong social element, they reinvent their operational mechanisms from a business perspective to ensure long-term sustainability. In that regard, we define long-term sustainability for the compost plants as been financially self-sustaining (at least able to reach total cost-recovery). It is important to note that while financial viability is essential, long-term sustainability is determined by a myriad number of factors to include a sound marketing strategy, efficient operational system, amongst others; and which are considered here. The research aimed to provide a set of recommendations/ strategies for adoption by the LAs; and which are presented in this chapter.

The research included an economic (business and market), and technical analysis to understand the existing (and support further) operational (technical and business) strategies used by the LAs for municipal solid waste management[10]. The recommendations presented here are based on the assessment of the sub-optimalities in the operational systems of the compost plants. This represents important information for the LAs (waste management regulators/ service providers), who are constantly exploring a holistic approach in generating multiple benefits from waste reuse businesses. In this regard, the subsequent sections present two sets of recommendations on a:

c) **Strategic level –** focusing on the broader business architecture of the compost plants;
d) **Business level** – focusing on the technical optimalities of the compost production process along the entire value chain from waste (input) procurement to product finalization; and market and financial-related factors (e.g. market demand, marketing and pricing strategies, cost-recovery potential.

[10] For the purpose of this research project, waste management refers to the specific component of the value chain that focused on resource recovery from municipal solid waste (i.e. nutrient recovery from MSW composting).

5.1.1 Strategic Level Recommendations

- **Recommended Business architecture for compost plants**

Currently the four compost plants in Batticaloa operate under four different local authorities. The individual local authorities oversee the operations of the four compost plants and have the autonomy in decision-making on all resource allocations for the compost plants (finance, manpower, technology, etc.). The compost product produced by the four plants are marketed under the “Best-Comp” brand, with the plant name of the respective local authority. In this setting, the four compost plants can be considered as Strategic Business Units (SBU) of Best Comp business according the context of the operations of compost plants in Batticaloa.

Each SBU has its own autonomy and decision making capacity, but is mandated to report to higher-level authority. Whilst currently, the role of the higher-level authority is played by the ACLG/ CLG office; an additional suggested body can be an elected/selected corporate entity/committee which consist of business-level nominees of four local authorities and at least one member each from the ADCs and Department of Agriculture, to create balanced ownership and involved of these relevant stakeholders for the project. This essentially creates an avenue for nonaligned entities to support the compost plants in achieving their intended business outcomes.

At the business level, each compost plant can operate individually with an autonomy in decision-making within an agreed framework. They can have their own SBU objectives, marketing plans and operational plans. At the operational level, they can adopt their own production, marketing, pricing, and differentiation strategies. However, the differentiation and pricing strategies should be approved at the corporate level prior to implementation. This not only ensures that the SBU benefits from support of the corporate body but this will also help mitigate any negative effects from market competition, for example, among the different compost plants.

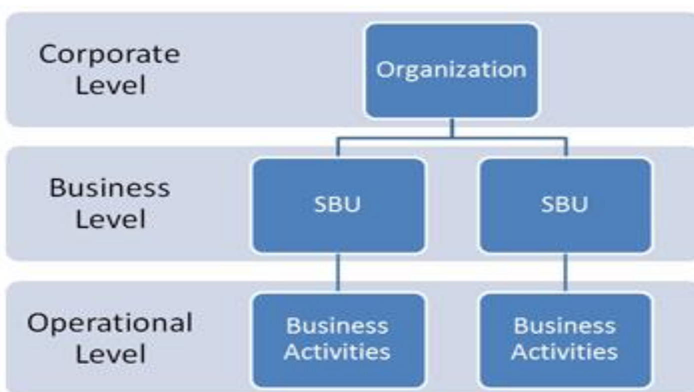

Figure 19: Generic SBU architecture
Source: http://www.bayt.com/en/specialties/q/97879/what-is-a-strategic-business-unit-sbu/

5.1.2 Business Level Recommendations

- **Technical recommendations**

The following recommendations are provided to improve the technical performance of the compost plants. It is important to note that the operational systems of all the plants are similar and so the recommendations below apply to all of them. For detailed assessments of each plant, reference should be made to section 3. The recommendations in view of the assessed sub-optimalities in the operational systems are as follows:

- **Waste input quality:** The local authorities in Batticaloa highly encourage waste segregation at source although this has not been enforced. Observing the input material and low supply of food and short term biodegradable waste evidence low degree of separation at sources such as institutes, hotels, and households. The lack of sufficient workers for waste sorting has also been a challenging factor for the compost plants. The preferred C:N ratio range for composting is 20:1 or 30:1, and as a thumb rule, this translates into one portion of green and one portion of brown waste, which is unlikely to be achieved with the present waste supply. The challenge of poor waste input quality invariably affects the quality of the compost product, in that end-users have noted the high sand content, low nutrient levels, and high inert material content, amongst others. The sustainability of the compost plants is dependent on market demand which in turn depends on the quality of the compost product.

  In the short-term and in the absence of enforceable measures for waste segregation, the compost plants can consider the following two approaches to address this challenge:
  - **Identify high nutrient waste sources** such as livestock waste (manure), fecal sludge, etc. (refer to table 7) and increase quantities of short-term degradable high N nutrient waste collected and used in production process. The cultivation of *Glyricedia Sepium* on compost plant premises is an option to be considered. Th**e** BMC, KUC, MPPS and MSEP compost plants have relatively large unused land area that can be used to cultivate high nutritional plants. Glyricedia sepium, a fast-growing, tropical, perennial hedge plant was tested as a source of N in organo-mineral fertilizer formulations. Average nutrient content of Glyricedia is 3.8% N, 0.32% P, 1.8% K, 0.8% Ca, and 0.2% Mg. The inclusion of Glyricedia leaves in compost piles in large quantities can substantially increase the nutrient quality of the compost produced.
  - **Implement polluter-pays policy** for institutions (restaurants, hotels) to reduce quantities of unsegregated waste received, or least reduce related operational costs incurred.

- **Windrow dimension:** According to the analyses, it was observed that the dimensions of the compost piles were practically difficult to manage as the turning of piles was done manually except for the BMC plant which uses a skid steer loader. It is recommended that the other plants invest in similar equipment to improve process efficiency. It was noted that a surface area to volume ratio (SA/V) of compost piles of less than 1 is important to increase the process efficiency. The SA/V of the compost piles observed for all the plants significantly exceeded 1. Given the hot weather conditions in the Batticaloa region, it is recommended that the pile sizes are kept at minimum required levels to maintain optimum conditions for composting. It is recommended to limit the windrow height to 1 - 1.5 m[11].

[11] Windrow dimensions should be more or less 1 m in height and 1 m in width given the climatic conditions in Batticaloa.

- **Protective cover for compost piles:** Experiences from other compost projects in the country (e.g. Pillisaru project) reveal that open windrows during the initial stage is successful. However, after the initial stage, windrows need to be moved to roofed/ covered areas to ensure an effective process. This is a requirement in the case of the all the compost plants, especially given the heavy rainfall in the area. High rainfall can raise the moisture content higher than the optimum, leading to a low oxygen environment (i.e. anaerobic environment). Additionally, high exposure to sunlight raises the need of watering of the piles, which in turn require more frequent turning of the piles and invariably increasing operational costs. Thus, undercover composting is preferred in order to maintain the controlled conditions for effective composting, and for which all the compost plants with the exception of the BMC plant need to consider in the adaptation of their operational processes.

- **Watering and Turning of compost piles:** For the stage of watering of the piles, the BMC plant was noted as the only plant with moisture content at the optimum range during week 1. All the other LAs have lower moisture content than the optimum range. However, at week 3, the moisture content improved in all plants. At the initial stage, regular moisture content inspection and addition is necessary and measurable using a digital meter or a field measuring method as shown in Box 2 and should be considered in the adaptation of the production processes.

- **Improved production and efficiency levels:** Table 3 depicts the design capacities and the operating levels of each compost plant compared to the design capacities. This is indicative of the relatively low performance of the compost plants given that they are operating significantly below their design capacity. Operating levels of the compost plants were estimated based on how much of the theoretically compostable waste is actually composted. Inadequate supply of the ‘correct’ quality of waste is noted to be a key constraint that currently reduces the effectiveness of the compost plants. The consideration of alternative waste streams such as fecal sludge for the production of a co-compost product[12] should be explored. This represents an opportunity to improve production efficiency and also the nutrient quality of the compost product (refer to Annex 1 and 2)

- **Quality monitoring and certification:** The majority of farmers noted the quality of the compost produced by the plants to be sub-par. They did not have confidence that the use of BEST- Comp would result in improved crop yield. Additionally, most farmers agreed that the low nutrient levels and physical contaminants of the compost product limited their use of the compost product. Agrarian development officers are the key informants on compost recommendations to farmers and thus the brand of compost to use. The development officers assess the compost quality based on lab reports provided by authorized agrarian laboratories. It is thus imperative that the compost plants conduct regular quality testing to assure the officers of the quality of the BEST-Comp product. This will incentivize them to promote the product to farmers. Product certification and on-field trials in direct collaboration with farmers (free compost product trials) represents an added-value to increasing adoption.

[12] Fortifer, a nitrate fortified and pelletized, faecal sludge and MSW co-compost; which addresses the current challenges associated with using ‘regular’ compost or even dried faecal sludge, perceived to be bulky, low nutrient content, related health risks from product.

- ### Market recommendations

The following recommendations are provided to improve the market performance of the compost plants. It is important to note that the operational systems of all the plants are similar and so the recommendations below apply to all of them. The recommendations in view of the assessed sub-optimalities in the operational systems are as follows:

- **Price segmentation and penetrative pricing strategy:** Price was a significant factor influencing farmers' purchasing decision of Best-Comp. The farmers noted that the current price of compost (Rs. 8/kg – wholesale price; Rs. 12/kg – retail price) was higher than they would like to pay and preferred to pay Rs.6 -7 per kg, which is lower than the current wholesale price being offered by the compost plants. The results rather show that a good strategy would be to reduce the price of the product and implement a penetrative pricing strategy (a lower market price than the prevailing competitive market price) to increase adoption rates. Compost plants can benefit from economies of scale from increased production which can allow them to reduce the compost price.
- **Marketing strategy – conduct result-driven pilot project campaign:** Best-Comp faces some strong competition large-scale compost producers, like ARAFA, CMP, etc. and livestock waste-based compost producers. In addition, to implementing a penetrative pricing strategy to increase adoption rates; strong awareness programs coupled with promotional initiatives such as testing with free samples will also be important to further increase market demand due to the fairly strong positioning of the competitors in the fertilizer market. There is a large number of farmers willing to use the Best-Comp product but are skeptical of the potential incremental yield benefits. The compost plants can create pilot projects in the localities to demonstrate the effect of BEST-Comp compost on different crops to convince farmers of product quality.
- **Product differentiation for different crops:** The four compost plants receive different qualities of waste input. There are some process differences between the plants, resulting in quality differences of the compost products manufactured. So far, this has become a shortcoming of BEST-COMP. Whilst, similar crops are grown in all the localities where the plants are based, some differences in crops cultivated exist and as such different soil nutritional requirements. An option is for the compost plants to conduct regular customer testing and evaluation to further tailor product features such as nutrient content levels, packaging and branding to specific consumer preferences.
- **Strategic partnerships with private entity distributors to reduce market competition effects:** A high reliance on the ADCs puts the compost plants at a risk especially in view of the fact that the ADCs also promote other compost brands (private sector) which are clear competitors. The LAs need to consider the option of directly supplying bulk loads to farmers with free or at least subsidized transportation to increase demand. Additionally, consideration of private sector entities (agricultural input suppliers or farming associations) as potential distributors is imperative. An additional consideration is the creation and promotion of a hotline number for compost orders and feedback from farmers. This has several benefits: a) it creates a direct link between the compost plants and the farmers; b) it can inform the production of the plant to adequately meet market demand.
- **Reposition the BEST-COMP product by increasing the brand awareness:** In 2003, the Sri Lankan Standard Institute introduced the SLS 1246 – which provides the standard requirements for compost produced from municipal solid and agricultural wastes. There is an opportunity for the plants to obtain SLS certification if they streamline their production process based on the SLS 1246 guidelines. An SLS

certification is an indicator of product quality which can significantly add-value to the BEST-COMP product.

- **Convert high sand content for positive effect by introducing value added ready mix:** One of the main complaints about the Best-Comp product is its high sand content. According to the recommended compost usage, compost needs to be mixed with soil, coconut coir and sand to get good material for crop cultivation. In Colombo, there are compost-soil-sand mixture products sold in 5kg, 10kg, and 20 Kg bags which can be used for agricultural purposes. Best-Comp can be sold as an intermediary product to private sector entities who produce and sell compost-soil-sand mixture products. On the other hand, the BMC, KUC, MPPS and MSEP plants can choose to produce the value-added compost-soil-sand mixture products and sell at a higher price to generate more revenue.

Financial strategy recommendations

The following recommendations are provided to improve the financial performance of the compost plants. It is important to note that the operational systems of all the plants are similar and so the recommendations below apply to all of them. The recommendations in view of the assessed sub-optimalities in the operational systems from a financial perspective are as follows:

- **Cost structure:** It is noted that the compost processing costs constitute a significantly small percentage of the total cost to the LAs, the current revenue earned by the plants is insufficient to cover the operational cost for compost plants (and covers only 2% of the annual operating costs excluding the depreciation for the KUC, MPPS and MSEP plants, while BMC is able to cover only 11%). The contribution of UNOPS towards the operational costs of the compost plants stands at 52%, 39%, 40% and 56% for BMC, KUC, MPPS and MSEP, respectively. The remaining balance of the operating cost which is uncovered, ranges between 37 – 59% (KUC have the highest balance) and for which the LA has to bear as a cost.

- **Improvements to break-even-point:** The calculated break-even point of segregated waste is 91%, 94%, 141%[13] and 102% of the design capacity for the BMC, KUC, MPPS and MSEP plants, respectively. At a 90% operation efficiency level and excluding depreciation, all the plants record a positive profit level with the exception of the MPPS plant which records a loss of Rs. 1.46 million/annum. This suggests that in order to ensure long-term sustainability, the plants need to increase their operation efficiency levels. This is achievable given the easy accessibility and availability of the waste resource input. Increased production can create economies of scale benefits through reduced product price and invariably increasing market share. With the possibility of producing a faecal sludge-based co-compost *(Fortifer)*, the higher price charged for the product can substantially increase the revenue generated.

  The financial sustainability of the MPPS plant is however highly questionable as the plant needs to operate at a very high level of operating level i.e. 141% of design capacity in order reach the break-even point where the current operating level is only at 16%. The BEP was further calculated under the scenarios of fixed costs excluding depreciation and annualized cost on observed data presented in Table 22. It can be observed that the BMC, KUC and MSEP plants can reach the breakeven point by operating at 65%, 70% and 83% efficiency level when the depreciation is excluded, respectively. The MPPS plant however cannot reach the breakeven point even when depreciation is excluded.

[13] The calculated BEP of segregated waste is 141% of the design capacity so that the plant cannot reach the BEP. As a result the plant is not able to cover its annual fixed costs thus it would record a financial loss every year.

Using the annualized cost on observed data[14], an improvement in the profit levels was observed for all the compost plants under increasing efficiency levels. This result is particularly important for the MPPS plant which posted negative profit levels even under 90% efficiency. This is because although a high volatility in the monthly costs was recorded for the other plants, a standard deviation of 22% of the monthly average costs for the MPPS plant suggests modest volatility in monthly costs, making the 'actual costs' for the MPPS plant more credible. It is noted that at a 75% efficiency level, the MPS plant posts a positive profit with or without the inclusion of depreciation and excluding any external support.

- **Production efficiency levels:** The results show that in general, the efficiency levels of all the plants are significantly low, with the MSEP plant having the lowest level. Additionally, the current compost production is only 8%, 3%, 4% and 3% of the design capacity for output for the BMC, KUC, MPPS and MSEP plants, respectively. The difference between the efficiency level calculated for input and the efficiency level calculated for output is mainly due to the work in progress (WIP) stocks. This result suggests that the operational efficiency needs to improve in order to reduce the WIP stock as this represents missed revenue and limitations on cash flow.

- **Marketing strategy to improve stock inventory levels:** A notable difference also observed is between the average monthly sales and production (unsold finished goods stock); where the former is significantly lower than the latter and KUC having the greatest difference. This result relates back to the marketing strategy modifications noted above – where all the composts need to increase their share of the fertilizer market through innovative approaches such as product differentiation, strategic partnerships for product distribution, result-driven product promotion, and repositioning of product brand.

Training and capacity development recommendations

There is a great opportunity for all the four compost plants to ensure long-term sustainability from adoption of the recommended adaptations to their operational systems. Capacity development of the relevant stakeholders is imperative for the implementation of the suggested recommendations for the following reasons:

- An **institutional gap** is expected to be created after the withdrawal of UNOPS activities. In that regard, it is recommended that an apex body consisting of representatives of SWM units of relevant councils, Provincial/District level officials of Department of Agriculture, Department of Agricultural Extension, Department of Agrarian Development (DAD), Divisional Officers (DOs) of DAD, representatives of Farmer Organizations (FOs), is established. The entity will represent an avenue for the sharing of resources, knowledge and lessons learned, discussion of common problems/ challenges and formulation of a seasonal production plan to manage the compost demand at the district levels, and development of strategies for market expansion, value additions and product diversification, etc.

- **Implementation of technological changes and best practices** for plant performance improvement require the provision of skill enhancement training on related subjects would further strengthen their capabilities. Additionally, training on new technologies such as development of faecal sludge-based co-compost *(Fortifer)* is imperative.

[14] It is important to note that these figures are significantly lower than the estimated cost figures and had high standard deviations, thus credibility of data questionable – with exception of the MPPS plant which had moderate volatility in the monthly cost figures.

- **Ensuring efficient labor allocation and high worker motivation** requires training for both compost facility laborers (on the operation and management of compost facility and composting process) and the waste collection workers so that both collection and compost facility laborers can be used on a rotational basis. This can help reduce challenges related to labor deficit and keep worker motivation high.

- **Implementation of innovative marketing and business strategies** require knowledge and competence training (on product marketing, building customer relationships and strategic partnerships, product diversification, and promotion) of the compost facility supervisors and other relevant officials.

- **Knowledge gap at the end users** level require the implementation of awareness and knowledge building programmes address both the monetary and non-monetary benefits of Best-Comp to farmers as well as disadvantages of inorganic fertilizers in the long-term context. Additionally, there is a lack of adequate awareness of MSW compost among stakeholder agencies and weaker linkages between MSW compost plant/production and grassroots officers. This requires training and awareness programmes on compost manufacturing process, quality certification and the importance/benefits of the MSW management programme to the local environment and the community; to stakeholder agency officers (Department of Agriculture (DOA), Department of Agrarian Development (DAD), Coconut Cultivation Board (CCB), Sri Lanka Cashew corporation (SLCC)) and the grass root level officers (Agricultural Officers (AO), Agricultural Instructors (AI), Agricultural Research and Production Assistants (ARPA) etc.).

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7. Annexes

Annex 1: Guideline for Co-composting

1. Co-composting

1.1 Process description

Composting of two or more decomposable raw materials together is common and is referred to as 'co-composting'. Co-composting of fecal sludge (FS) with organic solid waste is considered as an inexpensive and appropriate technology to enhance sanitation and waste management in low-income countries (Cofie *et al.*, 2016). The co-composting process is presented in Figure A below.

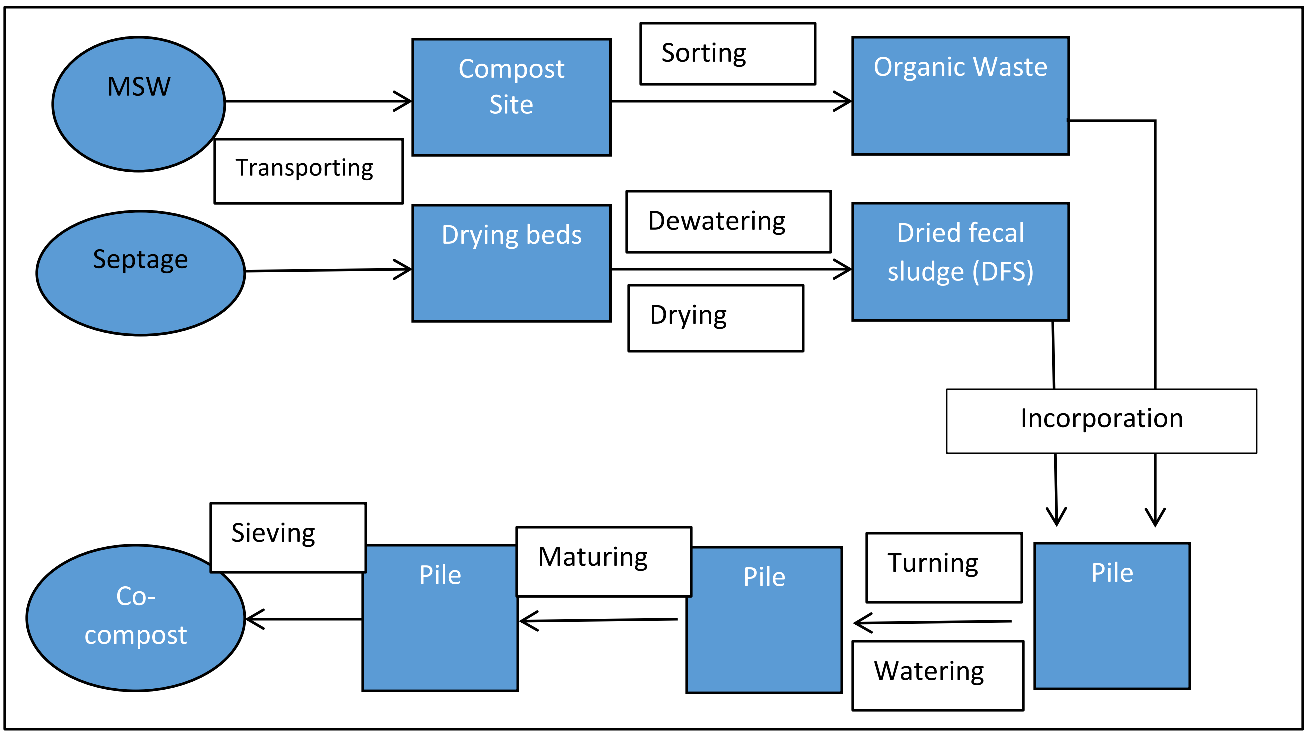

Figure A: Co-composting Process

1.2. FS Drying

The septage is dewatered to obtain dried faecal sludge (DFS) prior to be used as a feedstock for co-composting. Drying beds are the cheapest and the popular technology for dewatering of septage. In the drying beds, sand and gravel act as the media on which batch loads of septage are dewatered. Essentially, three layers of media with different sizes of sand and gravel are used for effective percolation. Figure B illustrates a typical cross section of a drying and filtration bed.

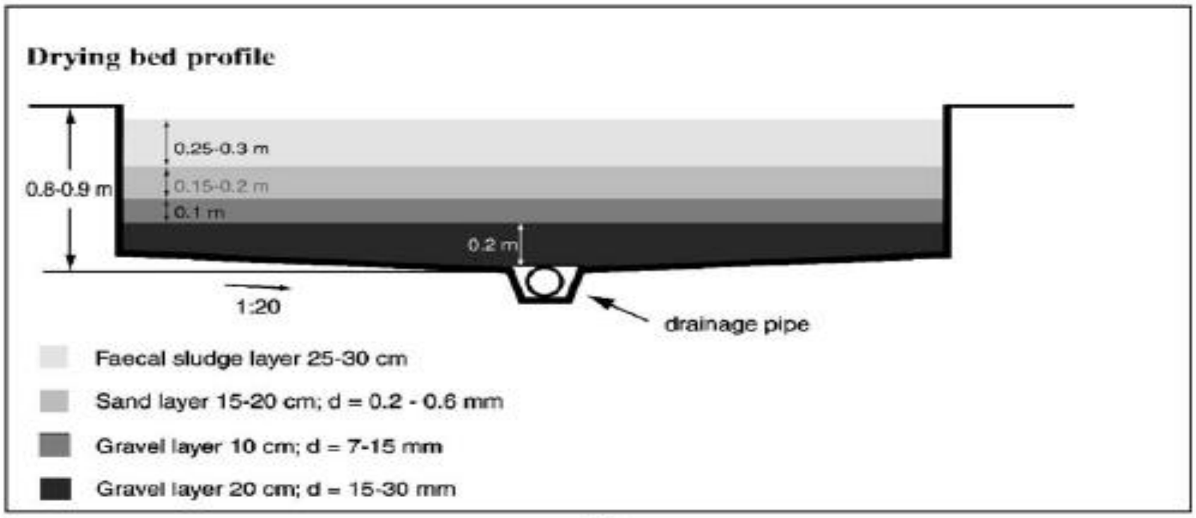

Figure B: Cross-section of a sand drying bed

Drying beds are used for the dewatering of septage through percolation and evaporation (mostly dewatering via percolation). Normally, septage is transported to the site by vacuum trucks. It can be directly fed into the drying bed or, instead of direct feeding, into the sludge-settling tank. In general, sludge should be sun dried for about 14-21 days depending on the weather conditions in the area. Figures C to H present drying process steps until the removal of DFS. After 21 days, DFS is manually removed (Figure G) and piled up for further treatment through co-composting, together with MSW (Figure H).

Figure C: Drying Beds with gravel (without top sand layer)

Figure D: Sludge after 2-5 days in Drying Beds

Figure E: After 10-12 days in drying beds

Figure F: After 20 days in drying beds

Figure G: Manual Collection of DFS

Figure H: Piling up of DFS

1.3. Co-composting of DFS and MSW

The sorted organic wastes and DFS are incorporated into a pile at the appropriate ratio of 3:1 to10:1 by weight as necessary. Essentially, MSW and DFS are piled up as alternate layers in windrows. Figures 10 - 16 further depict the steps involved in co-composting process.

Figure I: Delivery of MSW

Figure J: Waste comes as mixed waste

Figure K: Manual Sorting of MSW

Figure L: Incorporate MSW and FS as layers

Figure M: Compost piles

Table A: Co-composting Check List

Step	Description	Yes/No
1	Transporting septage to the site	
2	Discharge septage in to the drying beds	
3	Keep FS in drying beds for 14-21 days	
4	Remove DFS	
5	Piling up DFS	
6	Transporting MSW to the site	
7.	Sorting the waste in to categories E.g. Category 1 – Cardboard, Plastics, Polythene, Paper, PET bottles Category 2 – Banana leaves, coconut shells, coconut nuts Category 3 – kitchen waste, green leaves, market waste	
8.	Segregate category 3 waste as the input material for windrow composting	
9.	Building up a windrow pile – (Pile Dimension Height: 1-1.2m, Width 1- 3m)*	
10.	Check the moisture level of the pile daily: 1. Manually – by squeezing the composting material 2. With a moisture meter If water drips through fingers when squeezed, it indicate excessive moisture content, and if the material does not form a clump when squeezed, then the moisture content is considered to be too low. The optimum moisture level is in between 50-60%. If moisture level is less than 40%, add water up to 50-60 %.	
11.	Daily check the pile temperature by; 1. Manually - by inserting the hand into the pile and feeling the warmth 2. Using a Thermometer If the temperature rises up to 60-65 ^{0}C, turn the pile.	
12.	When temperature is stable, keep the compost pile static for 1 month	
13.	Sieve the compost	
14.	Weigh	
15.	Pack	

Annex 2: Guidelines for Pelletizing

2. Pelletization

Compost is bulky in nature with an average bulk density of 550 kg/m^3 and can be marketed in loose form. This creates many practical difficulties related to packaging, storing, transporting, handling, and application (farm level). Additionally, compost handling can often generate dust at the point of application, which may cause health and sanitation risks for farmers (Hara, 2011; Zafari and Kianmehr, 2012).

“Pelletization” can be applied as a solution to the aforementioned drawbacks of compost. Pelletization is the use of mechanical pressure to increase the material density while converting it into pellets. Typically, compost pellets are in cylindrical shape, 5–10 mm in diameter, and 25– 30 mm in length. This uniform size, shape, and other physical properties make it more convenient for storage and application (Hara, 2001). Consequently, pellets require 20–50% less packaging volume than powdered composts with a final specific gravity over 1000 kg/m^3 (Carter, 2010). Pelletization can contribute in increasing the market value of the compost product.

2.1 Process description

Pelletizing process consists of several steps as displayed in Figure N. Matured compost (co-compost) is first sieved with a recommended sized mesh and then mixed with binding agents, enrichment agents (optional), and water. Then the prepared mixture is used as an input material for the pelletizer (Figure N) and pellets are produced. Afterwards, the produced pellets are sieved and dried prior to packing and storing.

Figure N: Pelletization Machine

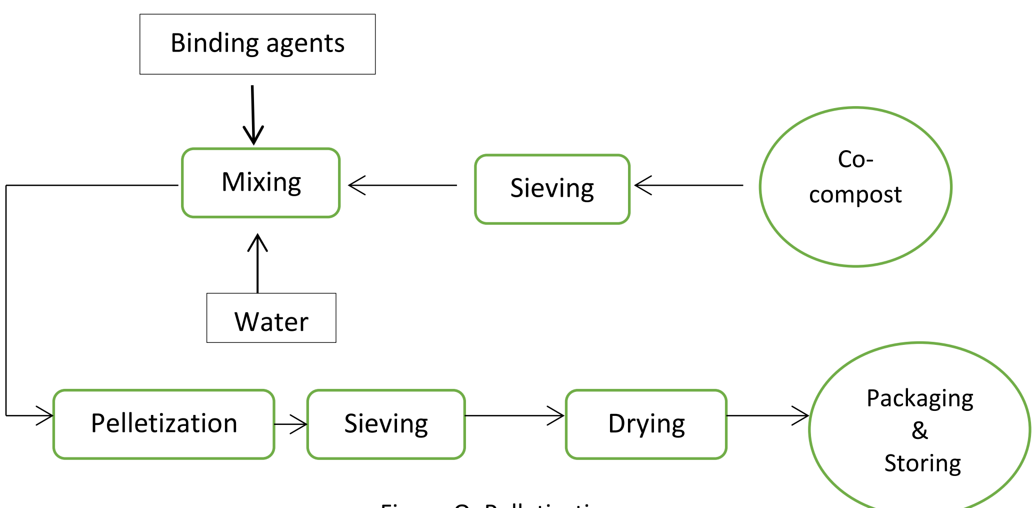

Figure O: Pelletization process

2.2 Moisture Addition

Moisture content of the final compost product is generally within the range of 20-25%. According to initial tests, appropriate minimum moisture content for pelletization is about 25%. Therefore, the moisture content of compost mixtures should be adjusted to 25% water content by adding water (Figure P) if required. The moisture content is measured with a portable moisture meter (Figure Q).


Figure P: Adding moisture


Figure Q: Checking Moisture

2.3 Mixing with additives

For the effective pelletization process, a binding agent can be added (optional) to the compost mixture to enhance the binding and de-binding properties of the pellets. A locally available material such as waste Rice Flour (RF) can be the binding agent at a concentration of 3% by mass. After the addition, the binding agent should be mixed thoroughly with the co-compost (Figures R and S). Note: Depending on the requirement, a nutrient-enriching agent can be incorporated to enhance nutrient value of co-compost. For example, adding Ammonium Sulphate [AS; $(NH_4)_2SO_4$)] can enhance Nitrogen (N).


Figure R: Adding additives


Figure S: Mixing additives

2.4 Pelletizing

Pelletizing is a mechanical process and the prepared mixture is fed into the machine (Figure T). Processed pellets are released through the vent while fine particles are sent through another outlet. The pellets produced are collected into an end tray aligning with the pelletizer (Figure U). After pelletization, the produced pellets may need air-drying, if its moisture content is high (Figure V).

Figure T: Feeding the pelletizer

Figure U: Pellets collected at outlet

Figure V: Pellets drying under air/sun

Table B: Check List for Pelletization of Co-compost

Step	**Description**	**Yes/No**
1.	Take sieved co-compost (desired amount in kg)	
2.	Lay on the ground	
3.	Check moisture content	
4.	Add moisture up to 25% and thoroughly mix	
5.	Add additives: either Binding Agent or Enrichment Agent	
6.	Thoroughly mix	
7.	Put in to a bucket	
8.	Place two bags, one at the dust outlet and the other at the pellet receiving vent	
9.	Check the machine's die for foreign materials (e.g. metals, stones)	
10.	Start the machine and run for about 1 min to stabilize the operation	
11.	Feed with co-compost using the filled bucket at a constant rate	
12.	Check the Ampere meter: If ampere rises over 40A, stop feeding and let the machine run free and stabilize below 20 A	
13.	Collect pellets in to the tray	
14.	After feeding is completed, allow the machine to run freely for 1 min	
15.	Switch off the machine	
16.	Drying collected pellets under the sun	
17.	Weighing the pellets	
18.	Bagging of co-compost pellets	