# Quantity Improved Analysis of Composting Process: A Case Study in Western Province in Sri Lanka

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***Abstract*—Inappropriate municipal solid waste (MSW) management is one of the major critical issues in Sri Lanka due to rapid urbanization and population growth and changing consumption patterns and human activities on natural environment producing more waste. Rapid urbanization, centralized industrialization and changing of consumption pattern of the general public of Western Province generate more waste than other province and it was selected for the current study. Due to this complex situation Waste Management Authority (WMA) was established under Western Provincial Council in 2004. Waste generation in the Western Province is approximately 60% from total waste generation of the country and from them about 75% are organic wastes. Composting is the most suitable method in the Western Province. Under WMA, 19 small and medium scale compost plants are maintained by local authorities of the Western Province. According to the capacity calculation of each plant, six plants are over capacity than design capacity and others are in lower capacity level. Design capacity of all plants is 155 ton/day and Operating Capacity of all plants is 82 ton/day. This variation was occurred due to poor operational efficiency. Poorly maintain plants were selected to monitor considering different physical, chemical, and environmental parameters to identify the problems. Height, width and length of the pile, turning schedule of the piles, temperature, moisture, and pH variation in different stages of composting process were evaluated in the selected plants. According to these evaluations, it was concluded that all factors are interconnected to produce compost and deviation of one factor directly affect to another factors prolonging the composting period. Turning and pile dimensions are directly affect to the other factors of composting process like moisture content, temperature and aeration process. All composting, windrows should be no more than 6 feet high and 12-14 feet length. For maximum production, temperature should be maintained between 50°C and 55°C after the few days and between 55°C and 60°C for several weeks, Moisture content between 40% and 60%. The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5. To minimize the loss of nitrogen in the form of ammonia gas, pH should not rise above about 8.5. Most of the heat produced in composting depends with consumption of Oxygen and production of Carbon Dioxide and water. Thus the waste pile must be sufficiently porous and materials should be placed loosely in the piles and compaction should be avoided. As the area is limited for composting piles in the plant proper operating is needed.**

**Keywords—composting; design capacity; quantity analysis; running capacity**

## I. INTRODUCTION

Inappropriate municipal solid waste (MSW) management in Sri Lanka is one of the major critical issues today[1]. Due to the urbanization with the increasing population growth in the country, the consumption patterns and human activities on natural environment create severe problems of waste generation and accumulation[2]. 85% of the generated solid waste are disposed basically in the open dumpsites and rest of are accounted for the composting and recycling processes [3]. Windrow composting is most widely used in the processing the MSW[4, 5]. In municipal areas in the country, local authorities are obliged by law to collect and dispose of solid waste put out by residents in areas in their jurisdiction. Collection and transport of solid waste are carried out by the local authorities with different levels of service.

Western Province was considered for the study. It is the smallest province of Sri Lanka when considering the area of the province. But it is the most densely populated province with about 5.4 million people and a daily floating population of more than 1.5 million[6]. Average population density is 1458 individuals/km$^2$. Rapid urbanization, centralized industrialization and changing of consumption pattern of the general public of Western Province create a more acute and complex problems than other province when considering waste management process. Result of this, Waste Management Authority (WMA) was established under Western Provincial Council in 2004, as per the statute No. 09 of 1999 as a supporting agency for local authorities in the Western Province. Subsequently this statute was amended as No. 01 of 2007 in order to obtain adequate legal provision in waste management with in the province. Waste Management Authority introduced two basic strategies as Zonal Concept and Seven Steps of Solid Waste management covering the main districts Colombo (642km$^2$), Gampaha (1386.6 km$^2$) and Kalutara (1606 km$^2$) in Western Province. These districts consists of 6 Municipal Councils, 13 Urban Councils and 29 Pradeshiya Sabhas (Subodha, 2012). According to the Zonal Concept of Waste Management, all local authorities of the province divided into seven zones with reference to six Municipal Councils and six zones are maintained Medium Scale Compost Plants under Waste Management Authority. This study was conducted to identify possible improvement areas to produce maximum quantity of compost through allocated areas of compost plants within suitable time period.

## II. MATERIAL AND METHODS

The research study was based on small and medium scale compost plants which are maintain under the Waste Management Authority in Western Province. One plant from each district in Western Province was selected to measure Density of MSW, Daily Designed Capacity, Daily Running Capacity and technical evaluation to identify strengths, weaknesses, opportunities and threats for improving of existing waste management practices in Western Province (Fig. I).

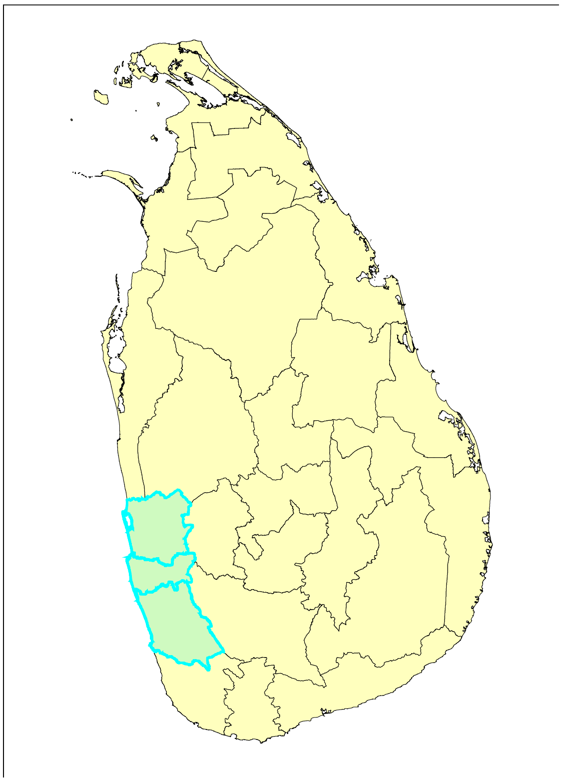

**Fig. I Western Province in Sri Lanka**

Three compost plants from each three district were considered. Randomly selected samples were prepared from fresh sorted waste from each plant. The density of collected waste was calculated by using measuring box from 45cm, 45cm, and 50cm with length, width and height respectively.

Daily Design Capacities were determined using site surveys data (length and width of building for windrow decomposing process). Plant dimensions and guidelines of WMA and Japan International Cooperation Agency (JICA) were used to calculate the Designed Capacity of compost plants. Measuring Daily Running Capacities were based on the dimensions of freshly prepared compost piles. After the sorting process, waste was prepared as a pile and width, length and height of the piles were measured to calculate the volume of piles. Weight of utilized waste (Running Capacity) for composting process was calculated by using calculated density value.

| Weight of the waste in the pile(kg) = Volume of pile x |
|---|
| (Running Capacity ) Density of sorted waste |

Technical evaluation was calculated considering the difference between daily designed capacity and daily running capacity of the compost plant. If there has a lower running capacity than designed capacity those plants were evaluated through technical processes. The most varied plants from each district were selected to technical evaluations.

Composting processes for each selected compost piles were evaluated measuring piles dimensions, temperature and particle size and also considering turning process. Height, width and length of the piles in different stages of the composting process were measured and the turning process within the composting period was identified having interviews with workers. Particle size of Municipal Solid Waste at first stage of composting process was taken approximately. Temperatures of the compost piles in the different stages of composting process was measured by using temperature probe (Reo Temperature Meter, Model is A36P). were used in this process. pH and Moisture Content also were measured.

## III. RESULT AND DISCUSSION

### *A Calculating the Density of Sorted Waste for Composting Process in Western Province*

To get an idea about density of collected waste after sorting process were measured by using waste in the each district of Western Province. Volume of container was 0.101250 m$^3$(45 cm*45cm*50cm). Three replicate samples from every plant were measured to get high accuracy value. Density of waste was calculated and further calculations on Design Capacity and Operating Capacity are based on this final density value.

TABLEI DENSITY VALUES OF SORTED WASTE

| Name of the Districts | Average Weight of the waste sample (kg) | Average Density of the compost plant (kg/m$^3$) |
|---|---|---|
| Gampaha | 33.37 | 329.55 |
| Kaluthara | 66.00 | 651.85 |
| Colombo | 86.33 | 852.67 |

Density of sorted waste=(329.5+651.8+ 852.7) /3
= **611.33 kg/m$^3$**

*B.Calculation of Design Capacity in Each Compost Plants in Western Province*

Using the field measurements of buildings (with roof and without roof area), lay out of waste processing facility was prepared. The unloading area, sorting area, service path, sieving area and compost storing area were separated from total area and rests of those areas were used as area for windrow decomposing facility. JICA guidelines and WMA instructions were used to calculate the design capacity of the plants. Volume reduction with time of the composting process is the very significant factor when calculating designed capacity.

TABLE I VOLUME REDUCTION OF WASTE WITH TIME IN A COMPOSTING PERIOD

| | 1$^{st}$ month | 2$^{nd}$ month | 3$^{rd}$ month | Total |
|---|---|---|---|---|
| Volume reduction % | 20 | 10 | 10 | 40 |

*Source: WMA guidelines*

It is assumed that area for 1$^{st}$ month is "V", then area for 2$^{nd}$ month is 0.8V and area for 3$^{rd}$ month is 0.7V according to volume reduction and it is also assumed that total area for three month composting process is equal to 100.According to this calculation 40% from total space is required for 1$^{st}$ month piling area. To calculate the volume, it was considered that pile height is 1.5m. Weight of waste was calculated by using calculated density value of 600kg/m$^3$. Daily design capacity of the each compost plant was calculated considering 25 working days of the month.

| Name Of the district | Number of compost plant | Total area composing (m$^2$) | Area 1$^{st}$ month (m$^2$) | Volume of waste in the area (m$^3$) | Weight of waste capacity for a month (ton) | Daily Design Capacity (ton/day) |
|---|---|---|---|---|---|---|
| Colombo District | 1 | 101.98 | 40.793 | 61.19 | 36.71 | **1.47** |
| | 2 | 405.35 | 162.14 | 243.21 | 145.92 | **5.84** |
| | 3 | 749.19 | 299.68 | 449.51 | 269.70 | **10.79** |
| | 4 | 372.75 | 149.1 | 223.65 | 134.19 | **5.37** |
| | 5 | 93.53 | 37.41 | 56.12 | 33.67 | **1.35** |
| Gampaha District | 1 | 886.7 | 354.68 | 532.02 | 319.21 | **12.77** |
| | 2 | 436 | 174.4 | 261.6 | 156.96 | **6.28** |
| | 3 | 751.75 | 300.7 | 451.05 | 270.63 | **10.83** |
| | 4 | 1149.79 | 459.91 | 689.87 | 413.92 | **16.56** |
| | 5 | 1121.15 | 448.46 | 672.69 | 403.61 | **16.14** |
| | 6 | 709.90 | 283.96 | 425.94 | 255.56 | **10.22** |
| Kalutara District | 1 | 735.72 | 294.29 | 441.44 | 264.86 | **10.59** |
| | 2 | 297 | 118.8 | 178.2 | 106.92 | **4.28** |
| | 3 | 340 | 136 | 204 | 122.4 | **4.9** |
| | 4 | 292.25 | 116.9 | 175.35 | 105.21 | **4.21** |
| | 5 | 260.78 | 104.31 | 156.47 | 93.88 | **3.76** |
| | 6 | 1106.64 | 442.66 | 663.99 | 398.39 | **15.94** |
| | 7 | 675 | 270 | 405 | 243.00 | **9.72** |

*C. Calculation of Running Capacity in each Compost Plants in Western Province*

Some plants are collected only sorted waste and some are collected both sorted waste and mixed waste for composting process. Amount of sorted waste, average volume of daily waste collection was taken and density value was calculated. Density of sorted waste is equal to 600kg/m$^3$ and below table can be filled with that value.

*D. TECHNICAL EVALUATION OF HIGHLY VARIED PLANT IN EACH DISTRICT OF WESTERN PROVINCE*

Running capacity highly varied plant in each district was selected to further analysis. Number 4, 5 and 6 plants respectively from Kalutara, Gampaha and Colombo district was highly varied and those compost plants were selected for the technical evaluation. Malfunctioning areas of those selected plants were identified considering different environmental (temperature, moisture content, pH) physical (height, width and length of pile, particle size) and human factors (number of labors, turning schedule). Pile height, width and length, particle size, temperature, turning schedule, and moisture content of the piles can be changed by people and proper

TABLE III DESIGN CAPACITY OF COMPOST PLANTS

| Name of the district | Number of compost plants in district | Average height of the pile (m) | Average length of the pile (m) | Average width of the pile (m) | Average volume of the pile ($m^3$) | Average weight of the waste pile (kg) |
|---|---|---|---|---|---|---|
| Colombo district | 1 | 1.18 | 2.40 | 1.5 | 4.24 | **2545.71** |
| | 2 | 1.35 | 2.49 | 2.09 | 7.00 | **4199.44** |
| | 3 | 1.11 | 7.25 | 2.80 | 22.58 | **13550.25** |
| | 4 | 1.98 | 1.38 | 1.56 | 4.26 | **2557.53** |
| | 5 | 0.93 | 3.26 | 1.56 | 4.73 | **2835.32** |
| Gampaha district | 1 | 1.24 | 2.14 | 1.8 | 4.79 | **2876.33** |
| | 2 | 1.74 | 3.9 | 1.86 | 12.62 | **7573.18** |
| | 3 | 0.75 | 4.13 | 2.14 | 6.61 | **3967.73** |
| | 4 | 1.16 | 2.40 | 1.95 | 5.42 | **3249.26** |
| | 5 | 1.26 | 1.65 | 1.39 | 2.90 | **1739.59** |
| | 6 | | | | | |
| Kalutara district | 1 | 0.96 | 3.90 | 1.80 | 6.77 | **4061.57** |
| | 2 | 1.09 | 1.86 | 1.50 | 3.06 | **1833.66** |
| | 3 | 1.5 | 3.54 | 1.8 | 9.55 | **5727.86** |
| | 4 | 0.46 | 2.92 | 1.74 | 2.35 | **1410.00** |
| | 5 | | | | | |
| | 6 | 1.03 | 3.18 | 2.17 | 7.13 | **4278.60** |
| | 7 | 1.63 | 3.04 | 1.76 | 8.71 | **5224.52** |

TABLE V OPERATING / RUNNING CAPACITY VARIATION FROM DESIGN CAPACITY

| Name of the district | Number of compost plants | Daily Design Cap. | Daily Run. Cap. | Run. Cap. – Des. Cap. |
|---|---|---|---|---|
| Colombo district | 1 | 1.47 | 2.55 | 1.08 |
| | 2 | 5.84 | 4.2 | -1.64 |
| | 3 | 10.79 | 13.55 | 2.76 |
| | 4 | 5.37 | 2.56 | -2.81 |
| | 5 | 1.35 | 2.83 | 1.48 |
| Gampaha district | 1 | 12.77 | 2.88 | -9.89 |
| | 2 | 6.28 | 7.57 | 1.29 |
| | 3 | 10.83 | 3.97 | -6.86 |
| | 4 | 16.14 | 2.19 | -14.37 |
| | 5 | 16.14 | 1.74 | -14.40 |
| | 6 | 10.22 | 13.11 | 2.89 |
| Kalutara district | 1 | 10.59 | 4.06 | -6.53 |
| | 2 | 4.28 | 1.83 | -2.44 |
| | 3 | 4.9 | 5.73 | 0.83 |
| | 4 | 4.21 | 3.12 | -1.09 |
| | 5 | 3.76 | 0.59 | -3.17 |
| | 6 | 15.94 | 4.28 | -11.66 |
| | 7 | 9.72 | 5.22 | -4.5 |

involvement of workers for those processes are very essential.

Pile height and width was about 1.5m and length was about 3m of No.4 pile from Kalutara. The plant should be turned after 2 weeks from pile preparation and then once a week until it completes six weeks. After 6 weeks it allows to be matured two weeks without turning. pH was lower at the beginning of the pile and it was reached to neutral. Moisture Content was in suitable range at first and after three month it was not sufficient to complete the process. Temperature of this plant was reached to proper condition in the first 2 month and composting process continued more than three and half month due to large accumulation of waste in this pile. Decomposing rate is significantly reduced due to improper management. It was observed that turning and pile dimensions are directly affect to composting processes longing the period more than four month.

No. 5 compost plant was 4 feet length, 3 feet width and height. These parameters were not changed during one month and 2nd months they were changed. Turning scheduled was once a week at first month while no turning at the 2nd month. pH was acidic condition after 12 weeks and pile was too dry due to high temperature inside the pile. Due to unfavorable condition for the process of decomposition this plant also got more than four month to complete the process. It was observed that lower operating capacity and turning process were directly affected to other parameters of composting process.

No. 6 pile from Colombo district was turned five times once a week. Pile height, width and length were 2, 4 and 12 feet respectively. After fifth turning, pile was kept 2 months without turning. Moisture Content was in range due to circulation of leachate in pile. In this plant, temperature was about 50°C and pH also was not favorable condition. It may be result of very short pile height.

## IV CONCLUSION

The results revealed that all physical chemical and environmental factors that considered this study are interconnected to produce compost and deviation of one factor directly affect to another factors prolonging the composting period. Maintenance of the proper temperature, along with oxygenation, is the basic consideration underlying the recommendations for windrow size and turning operations. All composting, windrows should be no more than 6 feet high and 12-14 feet length. At the end of the composting process, windrow temperature should be reached to room temperature and temperature should be slow down with the time of composting process. Temperature should be maintained between 50$^{o}$C and 55$^{o}$C after the few days and between 55$^{o}$C and 60$^{o}$C for several weeks, Moisture content between 40% and 60%. The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5. To minimize the loss of nitrogen in the form of ammonia gas, pH should not rise above about 8.5. Most of the heat produced in composting depends with consumption of Oxygen and production of Carbon Dioxide and water. Thus the waste pile must be sufficiently porous and materials should be placed loosely in the piles and compaction should be avoided. Prolonging composting period was a problem in the province as it has limited areas for composting plant. Therefore Operating Capacity of the plants is significantly reduced. Therefore proper maintain is necessary throughout the process for maximum production of compost.

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