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Optimal Design of Box Composting Plant: A Case Study Of Pakistan

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ABSTRACT. *In this research, a feasible design framework has been developed in order to design a box composting facility. Box composting technique is potentially a sustainable method to deal with solid waste management issues. Three different existing composting facilities in the different provinces of Pakistan have been studied to investigate the duration of composting under different weather conditions and therefore baseline durations for composting against the varying climate of different regions in Pakistan have been established. The data validated that the duration of the composting decreases with the increase in temperature. Moreover, a design framework that incorporates the weather conditions, as well as the density of waste, has been presented to calculate the sizes of composting and maturing boxes. A numerical design example has been successfully solved by assuming the data which proved the feasibility of the developed framework to design the compost facility as per any given requirements.*

Keywords: Composting, Integrated resource recovery center, Box composting, Solid waste management, Sustainability

1. INTRODUCTION

Composting is the process that converts degradable organic products such as plant leaves, kitchen green waste, and animal manure into useful fertilizers under a very controlled environment [1]. Every student of the subject knows well that the conversion of unusable ingredients of biological wastes into useful nutrients by mulching and other biological processes not only reduces the waste but also contributes towards sustainability by accelerating the biological life cycle. Organized composting as a technique of solid waste management also helps in the segregation of inorganic wastes and, useful recyclable and hazardous materials which if handled conventionally by dumping into a landfill would have not only wasted precious resources but would also have contaminated the natural resources such as groundwater in the long run. The current domestic waste management situation of the municipalities in Pakistan needs many improvements as the waste is partially collected and is subjected to dumping in open areas or burning which raises many environmental concerns. According to the Planning Commission of Pakistan, the urban population would be comprised of 50% of the total population by 2030. Due to this rapid urbanization and lack of a sustainable waste management framework, all major cities are facing the tremendous challenge of managing urban waste. So, composting provides a sustainable alternative to the waste management strategy that not only manages the waste rather also converts it into a valuable product like compost that is useable as an organic fertilizer [2, 3]. In Pakistan, an initiative has been taken by the joint venture of Akhtar Hameed Khan Memorial Trust (AHKMT), an NGO, UN-HABITAT, and UN-ESCAPE in the form of, Integrated Resource Recovery Centers (IRRCs) [4]. IRRC has utilized the box composting technique and it has been the first initiative of its nature to deal with the ever-increasing solid waste issues. The box-type composting system is a patent technology introduced by Waste Concern Bangladesh in order to convert waste into compost. This system includes different steps from sorting out the waste to finally bagging the prepared compost [5]. This initiative has been proven to be very useful in terms of sustainably managing waste and providing the replacement of fertilizers. According to a study, the residents and management of a local society in Islamabad were surveyed to know about their satisfaction level with the under-operation IRRC facility in the society, and it was found that the majority of the respondents were satisfied with its performance [6].This paper proposes a methodology to optimally design the box composting plant i.e.: sizing of compost and maturing boxes, and investigates the field-based data of the currently functional IRRCs at different locations in Pakistan.

2. WORKING MECHANISMS OF COMPOST PLANT

The compost plant collects the domestic waste, door to door, and the waste is transported to the facility using the vehicles i.e.: mini trippers. The waste is dumped at the sorting area where it is segregated as biodegradable waste, recyclables, and rejects. The biodegradable material is then shifted to compost boxes where it spends sufficient time before moving to maturing boxes. After spending a period of time in maturing boxes, the prepared compost is bagged and stored. The typical layout of the composting plant is illustrated in Figure 1. It can be observed that the compost boxes are the major area occupying elements of the composting plant. The placement of main elements like compost boxes, maturing boxes, storage spaces, and offices can be adjusted as per the requirements of elements and the given available space.

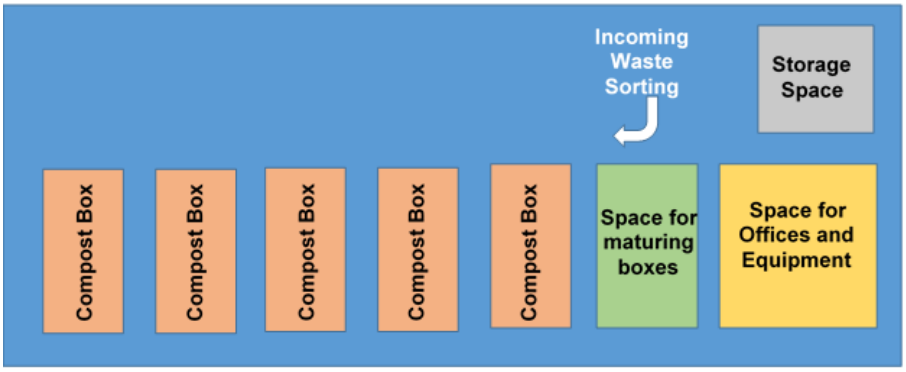

Fig -1: Typical Layout of the Composting Plant

3. METHODOLOGY

The design of the composting plant that mainly includes the sizing of composting and maturing boxes depends upon the capacity requirement based on the quantity of incoming waste, the density of the incoming waste, and the average temperature of the facility's location in summer and winter. The operational manual on composting for IRRC [7] suggests generic average values for the composting duration i.e. 45-50 days for composting and 15-20 days for maturing. Moreover, the sizing of the compost and maturing boxes is suggested to be done on the basis of density only, whereas the temperature factor is not discussed. In this paper, the study has been carried out to find out the actual composting durations in the different regions of Pakistan. The data has been observed at the IRRCs located in three different regions of Pakistan having differences in temperature. Furthermore, a design framework has been suggested to design the compost boxes by taking into account the weather conditions as well as the density of the waste. The data has been observed for different waste lots and their composting durations throughout a season, and the average duration has been worked out. The average temperature for analysis purposes is taken from online resources [8-10].

4. RESULTS AND ANALYSIS

The observed data is tabulated as Table 1. It shows the composting duration in both summer and winter seasons in different regions of Pakistan. It can be observed from Figure 2 that the duration of the composting increases as the temperature decreases and vice versa. Islamabad being the coldest region among the three has the highest days of composting in both kinds of weather whereas Sakrand being the hottest among all the regions has the lowest days of composting. We can also say that the number of composting days in the same region is more in the winter season as compared to the summer season.

Table 1: Duration of Composting in Different Regions of Pakistan

Sr. No.	IRRC Location	Province	Composting and Maturing Duration in Summer (Days)	Average Daily Temperature in Summer (Kelvin)	Composting and Maturing Duration in Winter (Days)	Average Daily Temperature in Winter (Kelvin)
1	Islamabad	Capital	90-95	Above 306.4	105-110	Below 293.7
2	Mardan	KPK	75-80	Above 309.2	90-95	Below 295.5
3	Sakrand	Sindh	65-70	Above 313.2	80-85	Below 301

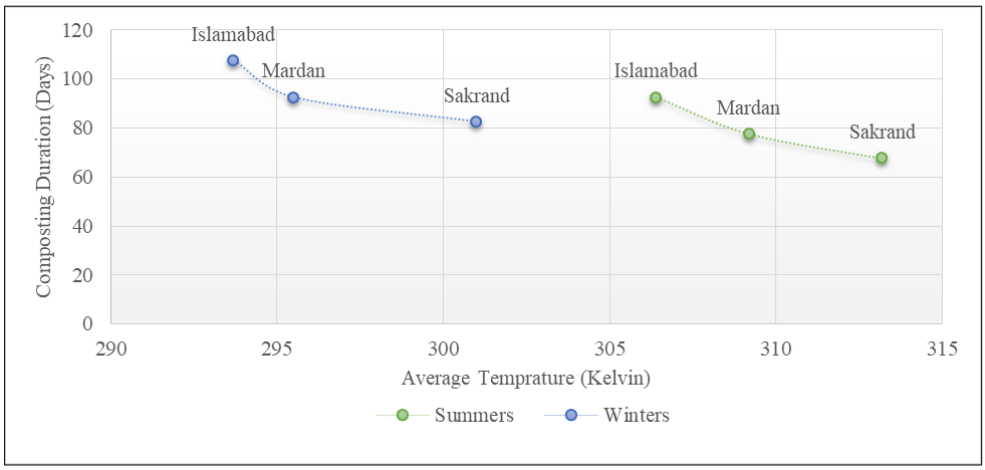

Fig -2: Effect of Temperature on Duration of Composting

5. DESIGN FRAMEWORK

The design framework comprises on determining the three key parameters required for sizing the composting and maturing boxes and placing all the elements of a compost plant as shown by typical layout in Figure 1, on the given footprint of the composting facility. The design framework is elaborated by Figure 3.

6. COMPUTATIONAL EXAMPLE

In order to demonstrate the application of the developed framework, an example has been designed by assuming the values, to calculate the sizes of compost and maturing boxes. Assumed input values are shown in Table 2.

Table 2: Assumed Values for Design Example

Sr. No.	Composting Facility Location	Density of waste (kg/ft^3)	Daily Input of waste (tonnes)	Daily Input of waste (Kgs)
1	Very hot weather area	9.67	10	10,000

As Table 1 gives us the baseline values for the duration of composting against different temperatures, we assume that for the very hot weather area, the composting duration is 65-70 days.

6.1 Sizing and Quantity of Compost Boxes and Maturing Boxes

Sizing is to be done by manipulating the values of green waste density and the quantity of daily incoming

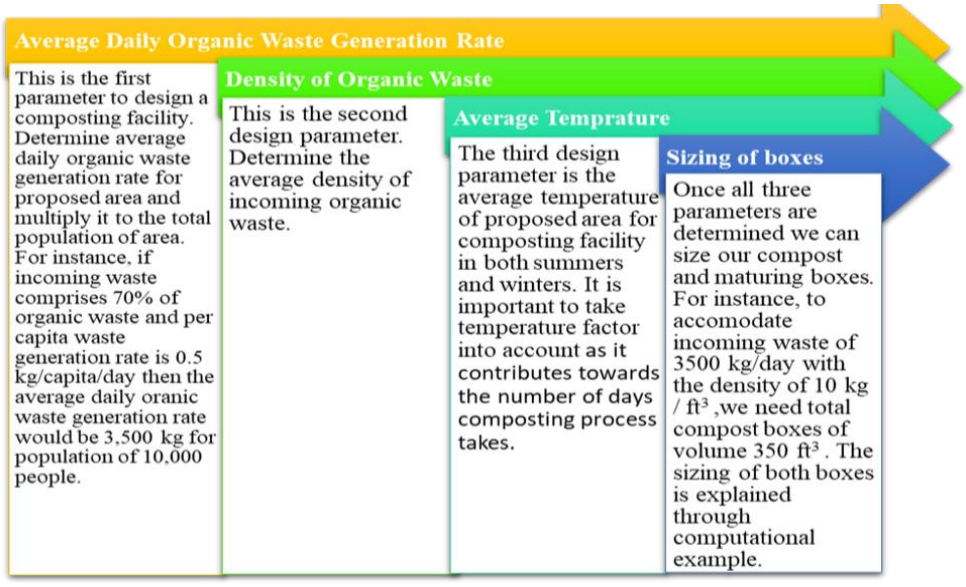

Fig -3: Design framework to optimally design a composting facility

waste. Moreover, the number of days required for composting may be worked out by considering the temperature of the planned area. It is worth noting that the number of boxes is to be adjusted in such a manner that it shall accommodate the daily demand of waste in all weathers without creating any backlog. Therefore, in this example, the total number of compost boxes is worked out as 48 whereas 1 compost box can accommodate 10 tonnes of waste. The size of one compost box is 7' x 6' x 24.6'. The idea is to fill 6 compost boxes at the same time by putting a layer of 1' in each box by using the layering technique. In this manner, 6 boxes will be filled in 6 days and 48 boxes will be filled in 48 days, hence completing the 48 days of the composting cycle.

Now, let's assume the density of pre-composted waste is 12.74 kg/ft3. The size of one maturing box is 7' x 7' x 16'. One maturing box has the capacity to accommodate waste from 2 compost boxes, thus 3 maturing boxes are required to accommodate waste from 6 compost boxes. In total, we have 9 maturing boxes to run the pre-maturing cycle for 18 days. Therefore, we combinely have 66 days to complete the composting cycle.

7. CONCLUSION

This paper has discussed the environmentally challenging issue of solid waste management in a country that is on the path of rapid urbanization. A design framework is presented to design the composting facility in accordance with any given requirements and conditions. The composting facility has the potential to tackle solid waste management issues by converting the waste into valuable organic fertilizer. The topic is still very less explored in the country as there do not exist so many composting plants. Although, one limitation of the study could be the less number of sample size owing to the small number of composting plants operating in the country., however, this research could be a stepping stone to designing such facilities in the future with more practical input of design parameters, therefore, increasing the working efficiency of composting plants.

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