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WINDROW COMPOSTING AS MUNICIPAL SOLID WASTE STABILIZATION – A CASE STUDY IN CHANDIGARH

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ABSTRACT

Rapid growth of the population and urbanization resulted in worldwide production of food and fruit municipal solid waste at alarming rate,which has become a global environmental issue and gained much interest due to their influence on environment, economy and society. More that 62 million tons of food waste is produced in India annually, approximately 15%, recycled through composting and landfills ranking third in terms of greenhouse gas emissions in India. The aim of this study was to investigate the optimum design of windrow composting plant and evaluate the composting potential of kitchen waste (food, fruit waste) with grass clippings in different combinations to establish the relationship between physico-chemical parameters (temperature, moisture content, pH, electrical conductivity, C:N ratio), hence the sustainable municipal solid waste management. Adjusting carbonaceous material and wet wastes in subsequent layer (30cm), which results in increasing the moisture content and improving C/N ratio.

KEY WORDS : Sustainability, Windrow composting, Organic compost, Solid waste management.

INTRODUCTION

The escalating global population expanded from 3.1 billion from 1960 to 7.4 billion in 2019 and expected to increase to 9.3 billion by the year 2050 (FAO, 2013), increased the erratic urbanization, massively, hence exponentially increased the food demand and in correlation solid waste generated, about 68.8 million tonnes (approx.) MSW per day which would increase to 300 million tons by the year 2047, however, only 19.36 is treated and rest 80.64% of municipal solid waste are used for unscientific land filling and dumping on outskirts of urban cities (Mor *et al*., 2006; Ambade *et al*., 2011; Barthod *et al*., 2018; Al-Rumaihi *et al*., 2020**;** Jalalipour *et al*., 2020; Rastogi *et al*., 2020). Hence the accumulation of solid waste is the main global environmental challenge in cities with high population density (Golueke, 1992; Sullivian *et al*., 2002; Mengistu *et al*., 2017; Al-Rumaihi *et al*., 2020). In this context, the city beautiful, Chandigarh which generates approximately 370 tons/day MSW, with large percentage of floating population from satellite towns (Mohali, Panchkula and Zirakpur), is major sufferer (Rana *et al*., 2015). Consequently, aim of the present study is to develop a prototype of composting facility to achieve sustainability in the management of the Dry biomass (leaves, Grass) and wet biomass (food, Fruit) generated in food services (Mess, Canteen, Cafetaria, juice corner) of the Post Graduate Government College for Girls. Sector 11 Chandigarh.

MATERIALS AND METHODS

Site Location

Chandigarh,one of the fastest growing cities in India with a decadal growth rate of 17%,lies at 76°47'14''E longitude and 30°44'14''N Latitude covering an area of 114 sq. km with a population of 1.05 million in the year 2011. The entire management of solid waste is taken care by Chandigarh municipal corporation. The windrow composting plant of 0.2TPD capacity located in Post Graduate Government College for Girls-11, Chandigarh,is source of present study.It consists screening facilities, solid waste separator, charging and composting units.

Study

This study was conducted for Eight months in 2019-2020 in the windrow composting plant situated in the campus of Post Graduate Government College for Girls, Sector-11, Chandigarh. The latitude and longitude of windrow site is 30.7583° N, 76.7841° E. The windrow composting plant (Fig.1) covers a surface area of 64 m^2 and composed of charging pit and two windrow pits, for the maturation of organic matter into the compost. The windrow plant is composed of area for mixing vegetable and fruit residues, storing the bulking agent (grass clippings) and compost screening. The wet waste (fruit and vegetables) and dry waste (Grass, Leaves), were used as the raw input materials. They are subjected to the windrow pile composting method in an open site area (Figs. 1-3)

Raw Material

A windrow composting process started with daily collection of solid waste from the food preparation sources (canteen, mess and juice corner) and its transportation to the solid waste management windrow plant. In the first stage, a static triangle windrow piles (3x4m; stage 1) consisting of dry and wet waste in equal proportion 1:1, were made and stored fortnightly. The first and foremost component of windrow was the charging unit in which dry and wet solid waste is added sequentially. The bottom layer added on brick lined charging unit was the dry leaves and grass (30 cm), alternate with vegetable and fruit waste (30 cm), which include refuse of food services (fruit, vegetable peeling, tea leaves, coffee residues) in three different layers. The repitation of the layers was done till the commulative pile reached 1.5m high. The pile (3mx4m), is turned on 6^{th} and 11^{th} day to architect aerobic conditions and to destroy insect larvae. The kitchen waste and dry garden waste (grass, leaves) respectively meets the

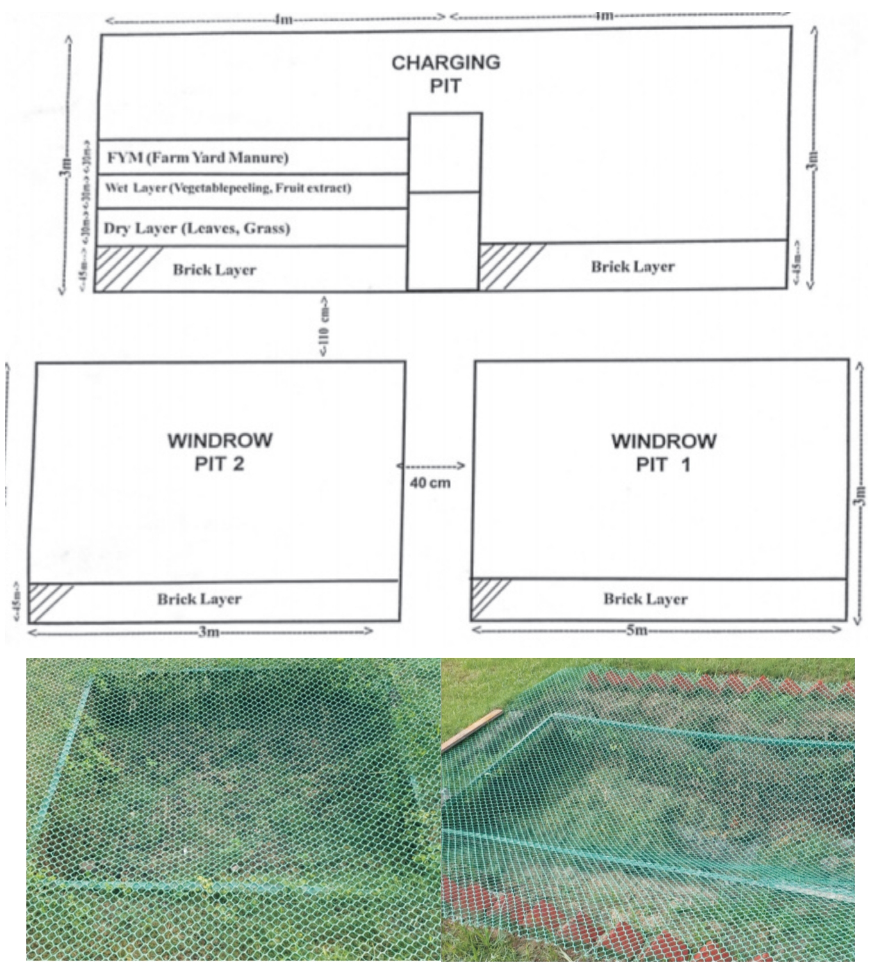


Fig. 1. Diagramatic layout of the windrow composting and field layout of charging and curing windrow unit

requirements of nitrogen and carbon. The blended waste was transferred to the covered charging pit of the windrow plant and after 4 wks, the raw organic waste transfered to aerobic pit1. In the next stage (stage 2), the aerobic windrow pit was covered again for 8 weeks, and during this the solid waste underwent curing process and after the stipulated time, the turning of partially digested organic waste into the uncovered window open pit 2, it marks the beginning of the stage 3.

The raw compost remains for 8 wks and before using it in the floriculture operations, the sample were tested for the different parameters (Temperature, Moisture content, pH, C:N ratio) as below and after standardizing the parameters, the organic compost was used as soil amendments in floriculture and horticulture operations after 6 months (stage 4).

Parameters monitored during the composting process

Temperature

The temperature was monitored weekly using the 'ReoTemp' compost thermometer in at least two points along the windrow pile and in three depths (30 cm from top, middle and bottom), over the period of 6 months.

Moisture content

For measuring the moisture content 1 kg mixed sample was prepared from 10 samples from different parts of windrow pit. In the present study, the container was weighed alone and then with a samples collected. First fresh samples were taken and labeled w_1 and on second instance the samples were placed in an oven at 105 °C for 24 hours. The resulting weight was labelled as the dry weight of the sample, w2. The moisture content (%age) of the mixed samples of food and garden waste was calculated using the following formula:

Weight of the wet sample (W_1) = (weight of container + wet sample) – weight of container

Weight of the dry sample (W_2) = (weight of container + dry sample) – weight of container

Moisture content of sample was calculated as:

$(W_1-W_2)/W_1 \times 100$

pH

For measuring the pH, 1 kg mixed sample was prepared from eight different cardinal points of windrow plant and ten grams of the sample was diluted with 100 mL of distilled water, and the electrode was rinsed with distilled water prior to the measurements using an electronic pH meter. The readings were taken twice to obtain a precise pH value.

Electrical conductivity

For measuring the Electrical conductivity, 1 kg mixed sample was prepared from eight different cardinal points as in process of pH measurement and ten grams of the sample was diluted with 100 ml of distilled water, and the electrode was rinsed with distilled water prior to the measurements using an EC meter and EC measured twice to obtain a precise value.

Carbon: Nitrogen ratio

A mixture of compost from food waste and garden waste with bulking agent was prepared and heated at 70°c for 24 hrs and the sample was cooled and powdered and 2gm sample taken from blended mixture was placed in a small aluminium cone and a CNHS-O analyzer was used to determine C/N ratio.

RESULTS AND DISCUSSION

Presently,the sustainable municipal solid waste management was demonstrated through the windrow composting,a waste-treatment technology, which greatly influenced by physico-chemical parameters (temperature, moisture content, pH,electrical conductivity, C:N ratio) during the composting process and the addition of bulking agent (grass clippings) was evaluated on different parameters and the data recorded pertaining to these parameters were recorded.

Temperature

Temperature,a proper indicator, plays an importance role in aerobic bio-conversion of the organic waste in three phases, the mesophilic (20 °C–45 °C), thermophilic (45 °C–70 °C) and curing phase. In the present study, the temperature was monitored weekly at two cardinal points of windrow at the depth of 30cm. The recorded data pertaining to the temperature, depicts that the pre-temperature (55-60 °C) at time of compost induction in charging pit, attained thermophilic phase (66 °C) in the initial two weeks (Fig.1), as composting, an exothermic process results in elevated temperature attributed to the increased biological activities,in which microorganisms attack the soluble and degradable compounds, indicates the extreme reduction in carbon organic matter (Wong *et al.*, 2008; Francou *et al.*, 2008; Zhang and Sun, 2016; Hemidat *et al.*, 2018; Kim *et al.*, 2018; Jalalipour *et al.*, 2020). The persistent elevated temperature thermophilic phase (>60°c), affects the decomposition, as it slows down due to high evaporation and deactivation of the compost microorganisms (Sincero and Sincero, 1996; Rana *et al.*, 2015; Mohee and Mudho, 2005; Mengistu *et al.*, 2017; Al-Rumaihi *et al.*, 2020; Pena *et al.*, 2020). During the initial decomposing active phase (2 weeks), the temperature fluctuations were recorded, hence more turnings (three) on 6th , 10th and 14th day and two in 3rd, 4th and 5th week and 6th week onwards, the pile was turned once a week. The turnings were required to destroy insect larvae and provide aeration, to maintain the temperature. Subsequently the temperature drops to 60 °C in the next 2 weeks and remained around 50 °C in 4-6 weeks before declining sharply in the curing phase,reaching constant mesophilic phase (40 °C) after 12 weeks. The curing phase, plays an important role in the maturation and stabilization of all compost parameters. The constant temperature from 12th week onwards depicts decreasing microbial activities in compliance with the earlier reports (Sanchez-Monedero *et al.*, 2018; Rupani *et al.*, 2019; Cristina and Leahu, 2020; Jalalipour *et al.*, 2020; Pena *et al.*, 2020; Rastogi *et al.*, 2020).

Moisture content

The moisture content of the mixed waste at the beginning of the process is 65% and in the subsequent weeks : 66%, 64%, 62%, 58%, 56%, 54%, 50%, 48%, 46%, 44%, 42%, 40%, 38%, 36% and 34%, 34%, hence the optimum moisture content for the composting process range from 34% to 66% for first 16 wks and remains unchanged thereafter till compost maturation. The histogram (Fig. 2) depicts the percent moisture content for complete cycle of 180 days during windrow composting. The initial moisture level is 65% which decreases significantly to 34% after 180 days. The initial reduction in the moisture level indicates the degradation of the organic matter in the mixtures. The heat and air-flow generated during composting evaporate significantly more water than is produced and tend to dry the material out (Mengistu *et al.*, 2017; Barthod *et al.*, 2018). The lower moisture content (40-54%) from 6th week to 12 week of composting,slows down the decomposition process due to reduction in the growth of micro-organism (Richard *et al.*, 2002; Mason and Milke, 2005**;** Francou *et al.*, 2008), however, the elevated moisture content (>60%), generate water logs with prevalent anaerobic conditions that halt the decomposition process and unpleasant odour(O'Leary *et al.*,2002, Gondek *et al.*, 2018; Hemidat *et al.*, 2018; Kim *et al.*, 2018; Rupani *et al.*, 2019; Al-Rumaihi *et al.*, 2020; Cristina and Leahu, 2020; Alalipour *et al.*, 2020; Pena *et al.*, 2020; Rastogi *et al.,* 2020; Voberkova *et al.*, 2020).

pH

The pH measurements are: 6.8, 6.4, 6.2, 6.2, 6.1, 6.0, 5.8, 5.6, 5.8, 6.0, 6.4, 6.8, 7.4, 7.8, 8.0, 8.2, 8.0, 7.8, 7.7 and 7.6 till 20 weeks and after that it remained unchanged till maturation of compost. The composting process began with nearly neutral range, however, a lower pH value (acidic) in the initial stages (1st week), attributed to the increased activity of microorganisms, ammonia volatization, production of fatty acids and microbial nitrification producing carbon dioxide, which combines with moisture content in mixture, resulting in generation of carbonic acid, which makes the composting mixture acidic with pH 5.6-5.8 in 8 wks. The

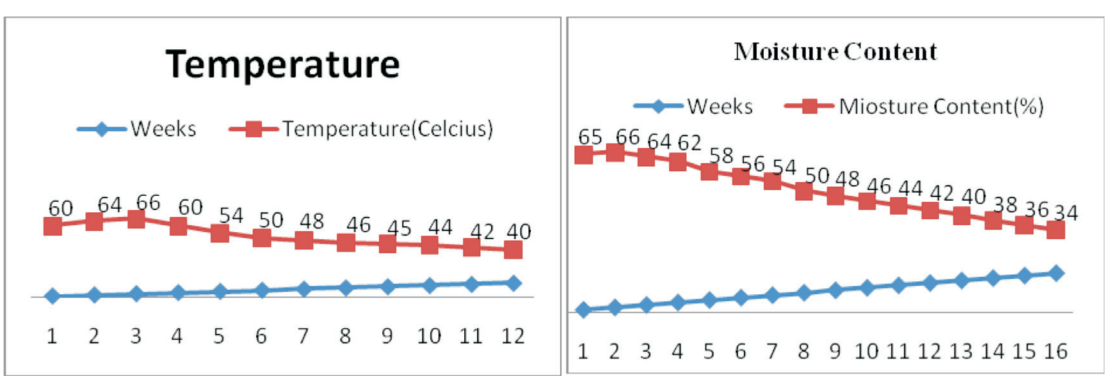


Fig. 2. Variations in Temperature (°C) and Moisture content (%) during the composing process in waste mass

progressive phase in windrow composting results in the e in pH elevated to 8.2 and ultimately stabilizes to pH 7.7-7.6 by the end of second phase in compliance with earlier studies (Sundberg *et al*., 2004; Francou *et al*., 2008; Zhang and Sun, 2016; Mengistu *et al*., 2017; Hemidat *et al*., 2018; Kim *et al*., 2018; Oviedo-Ocana *et al*., 2019; Rupani *et al*., 2019; Cristina and Leahu, 2020; Jalalipour *et al*., 2020; Pena *et al*., 2020; Rastogi *et al*., 2020; Voberkova *et al*., 2020), however, elevated pH during the curing stage due to reduced microbial activity, causes alkalinization of compost and hinder the survival of microflora of compost. However, there is no variable change observed in the measured values of the pH after 20 weeks onwards till the compost matured fully passing through curing phase. Hence, the pH of the compost product is 7.6-7.7 (Fig. 3).

Electrical Conductivity

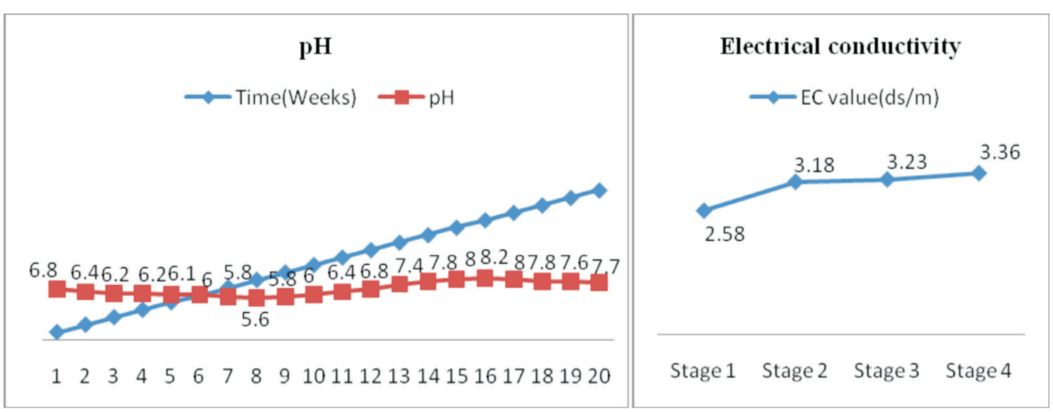
Electrical Conductivity (EC), another main parameter measured to reflect the salinity of the compost. The electric conductivity (EC) of the compost samples varied from 2.58 to 4.14 ds/m, the EC slowly increased to around 3.18ds/m, due to ammonia volatization (Huang *et al*., 2004; Garg *et al*., 2006, Jadia and Fulekar, 2008; Kim *et al*., 2018) and the elevated EC, increases the salt accumulation in the root zone, making soil physiologically dry and results in reverse osmosis and EC decreases at the later stage attributed to mineral salts precipitation (Wong *et al*., 1995), this range remained more or less stable until the end of process,resulting in the final EC of 3.36 ds/m (Fig.4), which is in preferred range of EC value 2-4 ds/m (Vander Gheynst *et al*., 2004; Chan *et al*., 2016; Silva *et al*., 2016; Gondek *et al*., 2018; Jalalipour *et al*., 2020) and EC value of compost above this range results in the hampering of the plant germination and growth and has negative impact plant vigour and vitality, in accord with the earlier findings (Sangamithirai *et al*., 2015; Zhang and Sun, 2016; Kim *et al*., 2018). The increased EC in compost can be countered by adding grass clippings, to the compost, increasing the aerobic conditions during the composting and reducing the gaseous emission and leachate production (Zhang *et al*., 2018).

Carbon: Nitrogen ratio

Carbon to Nitrogen (C/N) ratio, an important parameter, provide an optimal conditions for composting process. A biodegradable carbon-nitrogen (C/N) ratio of 30 has been found to be optimum for composting process. Lower C/N ratio increases the loss of nitrogen by leaching,nitrate mobilization and ammonia volatization and and air fail to penetrate the pile, which results in anaerobic conditions and cause odor (Francou *et al*., 2008; Xiao *et al*., 2009; Yan *et al*., 2015; Artemo *et al*.,2018; Ayilara *et al*., 2020). The C/N ratio during composting process has direct effect on the rate of decomposition, as high C/N ratio,the microorganisms activities will be reduced and the rate of decomposition slows down attributed to immobilization of nitrogen. In the present studies, the solid waste (Dry and wet) with bulking agent (grass clippings), rich in cellulose and lignin, was used in composting process, hence required more incubation time in relation to other compost materials, bulking agent (grass clippings) reduces the C/N ratio and improves aeration and results in conditioning of compost (Hua-Shan and Wei-Hsiung, 2006; Saad *et al*., 2014).

CONCLUSION

Windrow composting, an open system of a



Figs. 3-4. pH and Electrical conductivity variations during the composing process in solid waste mass

controlled bio-conversion of organic waste, is most common due to its low operating costs, simple layout and reproducibility in compost stabilization process. It is a fundamental process and presently used to process kitchen waste and garden waste. Enormous quantities of vegetable and fruit wastes were produced globally and composting can be a feasible treatment to stabilize their physico-chemical paramete to accelerate microbial decomposition and provides reproducible blue print to stabilize the solid waste for its use as organic fertilizers.

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