Drum Composting : A Unique Solution in Environmental Engineering for Biodegradable Waste Management and Electricity Generation

** Sachin Salve*
*** Sunil Shinde*
**** Kunal Bhojwani*

Abstract

In Civil Engineering or rather in Environmental engineering, waste management is a very tedious problem nowadays. This paper discusses the drum filling process as one of the best methods of biodegradable waste management technique, as it reduces tonnes of biodegradable waste from the environment and some innovative investigations are found to validate the potential of collecting electrical energy from biodegradable waste. The energy is accumulated by inserting a moisture sensor into a drum filled with compost to allow flow of ions to generate electricity. In addition, this research has the ability to light up small LED light which can be used for low power electrical consumption appliances like lamps, torch, etc. in the future.

Keywords : Biodegradable waste management, compost living plants, generation of electricity, organic energy

I. INTRODUCTION

Waste is now considered one of the leading civil engineering and environmental problems of the modern world. Due to the increasing amount of waste generated because of human activities, one of the specific objectives of environmental protection is proper waste management [1]. If waste is not managed properly, the problem of waste can be a huge burden for future generations. Introducing citizens with the need for adequate waste management is necessary because citizens are the greatest generators of utility waste. According to the criterion of formation, waste is divided into household (municipal) waste, waste in the public area, industrial waste, construction waste, agricultural waste, sediments and sludge from waste waters, sewage, septic tanks, and street drains [2]. The municipal waste consists of varied scrap arising as a by-product in households, institutions, stores, shops. It occurs in various forms such as waste (animal and vegetable sources), ash, paper, cloth, cardboard, objects made of rubber, wood, glass, leather, porcelain, furniture, household appliances, etc.

Open fermentation and decomposition of food residues mixed with other waste not only creates an unpleasant smell that is spread by wind in the environment, but also provides ideal conditions for the rapid spread of various infectious and pathogenic microorganisms and viruses [3], [4]. At the same time, atmospheric water passes uncontrollably through the

Manuscript Received : April 14, 2021, Revised : May 5, 2021, Accepted : May 7, 2021. Date of Publication : June 5, 2021.
* *Sachin Salve* is a Asst. Prof. Civil Engineering Department, Deogiri Institute of Engineering & Management Studies, Aurangabad, India.
Email : sachinsalve@dietms.org ; ORCID iD : https://orcid.org/0000-0001-8210-2374
** *Sunil Shinde* is a Head, Civil Engineering Department, Deogiri Institute of Engineering & Management Studies, Aurangabad, India.
Email : sunilshinde@dietms.org ; ORCID iD : https://orcid.org/0000-0002-3744-8066
*** *Kunal Bhojwani* is a UG Student, Civil Engineering Department, Deogiri Institute of Engineering & Management Studies, Aurangabad, India.
Email: kvbhojwani47@gmail.com ; ORCID iD : https://orcid.org/0000-0001-9974-3741
DOI : https://doi.org/10.17010/ijce/2021/v4i1/160810

waste dissolving a variety of harmless as well as harmful ingredients, spreading them to the wider environment. This represents a latent risk of water contamination that cannot be underestimated. The modern treatments of solid waste include waste reduction, reuse, recycling, drum filling, energy production, incineration, and dispose.

Drum-filling, as a modern way of treatment of municipal waste, is an exothermic process of biological oxidation, during which the organic substrate is subjected to aerobic biodegradation under the influence of microorganisms in conditions of increased temperature and humidity. In the process of biodegradation, the organic substrate undergoes physical, chemical, and biological transformations where a stable humid final product is created. This product is valuable for agriculture, both as an organic fertilizer and as a means of improving soil structure [5], [6].

Aerobic (exposure of waste to air and contact with sunlight) waste stabilization research was conducted for a duration of 51 days in three metallic drums, with a capacity of 200 L. The composting drum must be filled in fixed proportion of 2.5:1 as food waste to garden waste by weight. Effect of the growth of plants, turning of waste into composting process, and micro-bacterial inoculation were observed. To provide natural air ventilation (aeration), 16 holes of 10 mm were made on the circumference of the drums. The fundamental parameters such as moisture content, pH value of compost, and temperature were tested regularly to monitor the progress of biological process of compost [7].

The following types of waste (bio-waste) can be composted :

(1) Bio-waste Rich in Nitrogen (50%) : Fruit and vegetable residues, peel of fruit and vegetables, coffee and tea dregs, grass cuttings, weeds and plant residues in the garden, and withered flowers.

(2) Bio-waste Rich in Carbon (50%) : Leaves, chopped brushwood, straw and hay, fruit and grapes pruning residues, sawdust, needles of conifers.

Electricity is generated from decomposed manure. The experiment does not produce any effect on the plant as well as the environment. Photosynthesis is the process by which plants make their own food due to which green plants and certain other creatures convert solar energy into chemical energy. During the photosynthesis process, free plants absorb solar energy and convert minerals, water, and carbon dioxide into oxygen and energy rich compounds (electrons) [8]. This process helps to generate some bacteria and protozoa use the energy from sunlight to produce glucose from carbon dioxide and water. Aspects of consideration include easy embedding and stem moisture content. For this research we have used moisture sensor named as SKU: 12251 which helps to absorb moisture from the manure and generated the electricity.

II. MATERIALS AND METHODS

The common material for drum filling is :

(1) Drum (200 litres capacity)
(2) Sampling of plants
(3) Coco peat
(4) Coconut coir
(5) Dry organic waste (biodegradable waste)
(6) Bio-sanitizer
(7) Little amount of water
(8) Moisture sensor
(9) LED light

Fig. 1. Waste Sampling

A. Waste Sampling

The biodegradable fraction of municipal solids waste (MSW), that is, food waste (FW) was treated by composting process. To maintain the optimum moisture content level for composting, garden waste (GW) was used as bulking agent.

Waste material such as coco-peat, coco-coir, etc. were used with materials mentioned next for proper distillation and fast process of composition takes place. The FW was mainly comprised of vegetables, reties, residues of carrot, residues of fruits collected from a restaurant, hotels, and mess, whereas grass trimmings, and plant leaves formed the major fraction of GW. The waste food waste garden waste was mixed in a fixed ratio of 2.5:1 by weight to ensure homogeneity of the mixture. The resulting waste were termed as compost (manure).

B. Composting Drum Design

The research was conducted using three metallic drums of 200 L capacity. To provide natural air ventilation (aeration), 12 holes of 100 mm were made on the circumference of the drums. Divide the drum into three levels, each level consisting of three holes alternate to other levels. The edges are chiselled well to avoid cuts and provisions were made to avoid the corrosion of metallic drum by painting the drum from the outer periphery. Facilities were provided for collection of leachates at the bottom of drums. An additional drum was used for the turning of sample from drum to get more stable manure like compost.

Fig. 2. Composting Drum

C. Process of Composting

The process of composting was conducted in open space like gardens, terrace to allow natural aeration. Plastic tray was kept below the drums for the collection of leachates, above which drums are laid on bricks or Autoclaved Aerated Concrete (AAC) blocks. For the sampling purpose, approximately 80kg of homogenized municipal waste was added in each drum in alternate layer with coco-peat and coco-coir with little amount of water. Temperature in all the drums was measured at middle and bottom portions once in a day using a battery-operated handheld thermometer. Various tests were carried out to find out the product quality parameters such as C/N ratio, pH, total organic matter (TOM), electrical conductivity (EC), moisture content (MC), were conducted for 51 days. The micro-biological degradation was monitored for the waste for 51 days.

D. Installation of Moisture Sensor

Installation of a capacitive soil moisture sensor probe is simple. However, there are a few important points which should be considered to achieve good measurement result. So, here is a composting drum in which sensor is to be installed. It is mandatory to fully bury the probe including the black housing. A very good contact with the

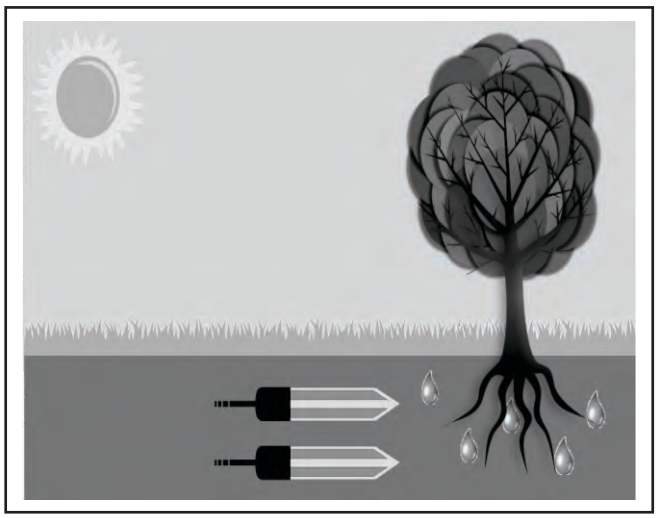

Fig. 3. Installation of Moisture Sensor

surrounding compost with no air gaps is very important because air gaps lead to wrong compost moisture measurements. The density of the surrounding compost influence the measurement signal. The compost must be properly compressed.

III. METHODOLOGY

The selection of plants and materials for adopting city farming method is done and to achieve the objective, namely, decomposition of biological waste effectively. The bio-sanitizer meets moisture and multiplies at faster rate. It consumes all the dry waste and produces manure which flourishes the plants. Not only this, it can also be used as a fertilizer for other plants on ground as a soil conditioner. It has the property to enhance NPK [(Nitrogen (N) - Phosphorus (P) Potassium (K))] nutrients in the soil by placing moisture sensor in manure which is formed after the stabilization of waste in drum, which meets moisture and through which ions are transferred in sensor and generation of electricity is done.

Carbon dioxide is produced and released as rhizo-deposits (e. g. root exudates) by plants and it is utilized by micro-organisms that return carbon dioxide into the atmosphere. Metabolic energy collected by micro-organisms by means of anode which has +ve ions acceptor. These electrons run due to the potential difference of ions from the anode through an electrical circuit with a load or a resistor to the cathode. Therefore, electricity is generated which can be used, for example, to lamp lights. To maintain electro-neutrality, protons are transported through the membrane into the cathode where oxygen reacts with protons and electrons to form water. It is possible to produce green electricity by non-destructive harvesting of the rhizo-deposits (mainly carbohydrates) of the plant in the system.

This has important environmental advantages such as no transport of harvested biomass, preservation of nutrients in the ecosystem, use of a renewable energy source, and no combustion or extra green-house gas emissions during production. Also, it helps to generate small amount of electricity which can be used for future. This research can be implemented in natural environments such as for gardening, as well as at night decoration clubs, streets, and commercial buildings where wetlands are observed. Thus, in the future, worldwide wetlands with drum compost with salted soils might be transformed into green power plants generating electricity in a carbon neutral way with good, composted manure.

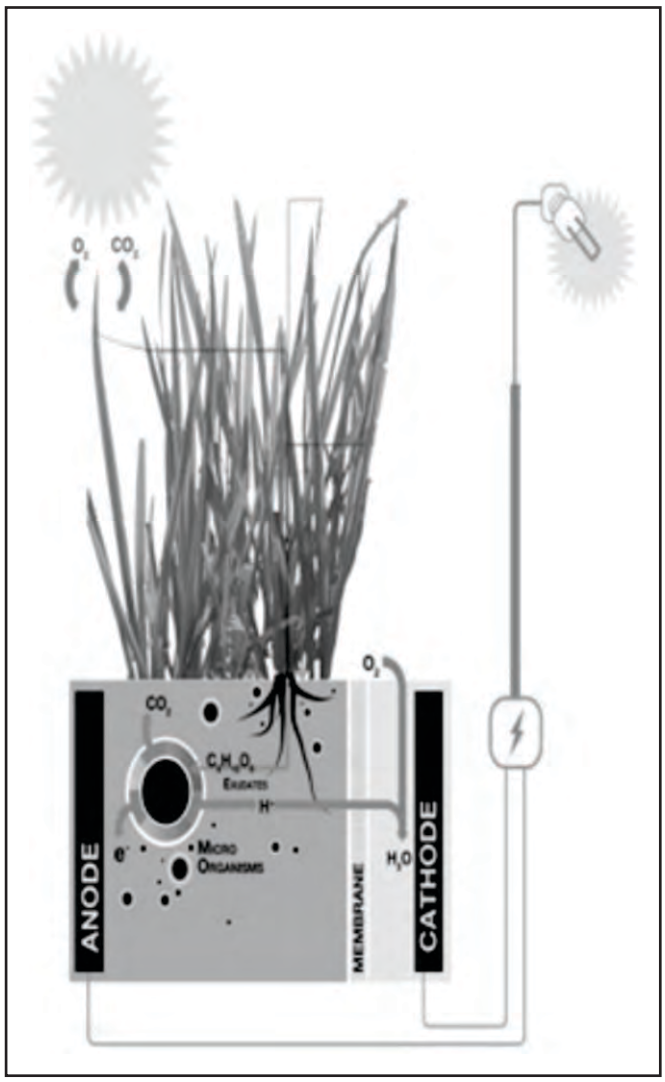

Fig. 4. Electricity Generation from Plants by the Process of Photosynthesis

IV. EXPERIMENTAL PROCEDURE

(1) Clean the drum from inside as well as from outside.

(2) Mark 10 – 12 numbers of holes on the drum each of 10 cm diameter.

(3) The hole should be cut in such a way that as the drum is divided into three parts, each layer should consist of four holes.

(4) The holes in the upper layer should be cut alternate to

layer that is below. These should come between each other.

(5) The edges should be chiselled well to avoid accidents during working.

(6) Now the drum should be painted well to avoid corrosion.

(7) The base layer should be laid with coconut coir in a thin form.

(8) The sampling should be protected with the help of coconut coir in such a way that all the samplings are planted and again a layer of coconut coir is laid.

(9) Coco peat is sprinkled and dry organic waste, for example, dry leaves, dry plats, domestic organic waste, etc. are laid.

(10) Bio-sanitizer is added in powder form and 10 litres of water is given to the drum.

(11) Within 3 to 5 days, the plants stabilizez, and addition of waste can be started as per standards.

After the stabilization of manure, place the moisture sensor in drum and electricity is generated. Once the plant stabilizes and the bio-sanitizer comes in contact with moisture, the development of culture starts and the culture settles into the atmosphere. It starts consumption of waste and produces manure. Within a few days the rate of decomposition becomes faster, and we can add 500 grams of daily waste.

This way, tonnes of organic or domestic waste can be decomposed by using simple methodology which results in decrement of waste saturation and utilization of this technique can be done in a profitable manner. Little electricity is also generated to run LED light. Within one to two months, we get flourished plants, fruits, and flowers according to the nature of a plant.

V. RESULTS AND DISCUSSION

This way plants grown from garbage or organic waste are healthier than plants grown in soil or ground. Efficient and economical use of waste can be adopted. There is reduction in decomposition of waste by other harmful methods such as land filling, incineration, etc. which pollutes the environment and human health as well. This is a good aspect of Environmental & Civil Engineering.

TABLE I.

COMPARATIVE HEIGHTS BETWEEN VARIOUS PLANTS AND TOTAL WASTE DECOMPOSED

Dates	12/1/2020	21/1/2020	12/2/2020	19/02/2020	7/3/2020	Total waste
Plants	June (height in cm)		July (height in Cm)		August	decomposed (kg)
	Day 1	Day 10	Day 21	Day 28	Day 45	
plumeria (1)	70.8	80	80.2	80.4	81	17.5
Plumeria (2)	70.6	70.8	70.9	80.1	80.5	17.5
Plumeria (3)	70.4	70.5	70.7	70.9	80	17.5
Hibiscus (1)	40.9	40.4	40.7	40.9	41.1	17.5
Hibiscus (2)	40.5	40.7	40.8	40.9	50	17.5
Hibiscus (3)	40	40.3	40.5	40.9	41.2	17.5
Canna (1)	50.3	50.3	50.4	50.5	50.5	17.5
Canna (2)	60.2	60.4	60.6	60.8	60.9	17.5
Canna (3)	61.2	61.3	61.5	61.8	62	17.5
Arabian Jasmine (1)	90.8	90.9	91.4	91.8	91.9	17.5
Arabian Jasmine (2)	90.6	90.7	90.8	90.9	91.2	17.5
Arabian Jasmine (3)	110.7	110.9	111	111.19	111.21	17.5
Papaya	132.2	132.6	132.8	132.9	133.5	17.5
Palm	10.7	10.9	11	11.5	11.7	17.5
			Total waste decomposed from drum filling method			2.45 tonnes

TABLE II.

COMPARATIVE HEIGHTS OF PLANTS GROWN ON GROUND AND FROM DRUM FILLING METHOD

Dates	12/1/2020	21/01/2020	12/02/2020	19/02/2020	07/03/2020
Plants	June (height in cm)		July (height in cm)		August
	Day 1	Day 10	Day 21	Day 28	Day 45
Plant grown from waste (palm)	10.7	10.8	11	11.5	12.1
Plant grown on ground	10.5	10.6	10.85	10.91	11.1

The manure which is formed by this method is used as fertilizer for agricultural areas, vertical farming method, green building method, gardening etc.

VI. CONCLUSION

Using waste for drum filling instead of throwing it largely depends on the level of socio-economic development, public awareness, and environmental policy. In India, apart from smaller amounts of conventional vegetable compost used as organic fertilizer, other organic residues are disposed off in open ground.

The advantages of drum filling are :

(1) It is a simple, cheap, and long-lasting technology. On an average 40 – 45% of the total mass of feed stock can be further used; maximum utilization of nutrients are necessary for use in agriculture (P, K, Mg, and micro-elements).

(2) Production of humid substances, useful microorganisms, and slow-dissolving nitrogen bacteria for landscape construction.

(3) It eliminates weeds and pathogens in the waste material.

(4) Reduces the total amount of waste on the basis of drum filling

(5) Reduces the range of burning of organic waste.

(6) It eliminates weeds and pathogens in the waste material.

As mentioned previously, it can be concluded that there are multiple benefits of drum filling-biodegradable waste management techniques. Therefore, it is necessary to gradually introduce drum filling process in each individual household.

REFERENCES

[1] A. A. Maynard, "Compost: The process and research," *Compost Sci. & Utilization,* vol. *2,* no. 1, 2000. Issue 966 of Connecticut Agricultural Experiment Station, Bulletin Connecticut Agricultural Experiment Station, 2000.

[2] D. Eddy, "Waste not, want not," *Amer. Vegetable Grower,* February 2000, pp. 32–33.

[3] J. Belien, L. D. Boeck, and J. V. Ackere, "Municipal solid waste collection problems: A literature rev.," 2011. Hub Res. Papers 2011/34, *Econ. & Manage., December,* pp.1, 2011.

[4] S. A. Tweib, R. A. Rahman, and M. S. Kalil, "A literature review on the composting," vol. *12,* pp. 124-127, 2011. *Int. Conf. on Environment and Ind. Innovation, Dept. of Chemical & Process Eng.,* Faculty of Eng. & Built Environment, Universiti Kebangsaan Malaysia 43600 UKM Bangi Selangor Darul Ehsan Malaysia. http://www.ipcbee.com/vol12/24-C10006.pdf

[5] P. A. Nwofe, "Management and disposal of municipal solid wastes in Abakaliee Metropolis, Ebonyi State, Nigeria," *Int. J. of Scientific Res. in Environmental Sci., vol.* 3, no. 3, pp. 107–118, 2015. Division of Materials Sci. and Renewable Energy, Dept. of Ind. Physics, Ebonyi State University, Abakaliki, Nigeria. https://nswai.com/docs/Management_and_Disposal_of_Municipal_Solid_Wastes_in_Abakaliki_Metropolis_Nigeria.pdf

[6] S. Aboulam, B. Morvan, and J-C. Revel, "Use of a rotating drum pilot plant to modal the composting of household waste on an industrial scale," *Compost Sci. and*

Utilization, vol. 14, no. 3, pp. 184–190, 2013. https://doi.org/10.1080/1065657X.2006.10702282

[7] D. Block and N. Goldstein, "Small scale system: Plans aboundsor in-vessel composting – Part I," *Biocycle,* vol. 39, no. 2, p. 40, 1998.

[8] Y. Eklind and H. Kirchmann, "Composting and storage of organic household waste with different litter amendments I: Carbon turnover," *Bioresource Technol.,* vol. 74, no. 2, pp. 115–124, 2000. https://doi.org/10.1016/S0960-8524(00)00004-3

About the Authors

Prof. S. B. Salve holds B.E. (Civil), and M.E. Structural Engineering degrees. He is working as Assistant Professor with Civil Engineering Department, Deogiri Institute of Engineering and Managements Studies, Aurangabad. He has published 5 papers in international journals and conferences.

Dr. S. D. Shinde holds B.E. (Civil), M.E, and Ph.D. in Civil Engineering, He is Head of Department (Civil Engineering), Deogiri Institute of Engineering and Managements Studies, Aurangabad.

K.V. Bhojwani holds Diploma (Civil Engineering). He is pursuing B.Tech. from Deogiri Institute of Engineering and Managements Studies, Aurangabad.