

# Design And Fabrication Of An Eco-Friendly Waste Bin For Household Solid Waste Segregation, Storage And Composting

Oladapo T. Okareh, T.K Ibidapo-Obe, S.A. Lateef

**Abstract:** Waste is a global issue and if not properly dealt with, poses threats to both public health and the environment. Storing of mixed wastes especially from homes, enables biodegradable materials to rot and decompose under improper, unhygienic and uncontrolled conditions. The study aimed at developing an eco-friendly waste bin for effective household solid waste storage, segregation and composting of the biodegradable wastes. Household solid waste composition was assessed from 32 households in three contrasting areas: Oluyole estate (Low-density area); Foko (High-density area) and Molete (Middle-density area), for four weeks to determine the quantity of wastes generated at household level. The generation rate for household solid waste was also determined and thereafter a waste bin (2ft X 2ft X 3ft) made from galvanized steel sheets that were purchased locally was fabricated and installed in one randomly selected household and tested for its suitability for storing and segregating solid wastes at source, with the biodegradable wastes converted into compost, using a family of 5 - 6 persons. The fabricated waste bin was made to store the waste for about 4 weeks and the compost quality observed at the end of 60 days. The analysis of the household waste composition showed food waste as the major component of the solid waste stream (39.9% - 48.6%). The household solid waste generation rate ranged between 0.45 - 0.60 kg/household/day. Compost was obtained from the biodegradable wastes after maturation, showing pH value of 9.28, nitrogen of 0.82%, organic carbon of 7.86%, potassium level of 43.61 Cmol/kg and available phosphorus 317.65 mg/g; indicating its suitability for both household gardening and farmland fertilizer. The time required for compost formation depends on the nature of the waste, the amount, and the ambient temperature. A major advantage of the bin as observed was that adequate control of the contents and process, prevent smell and fly nuisance commonly observed with other bins. The bin can conveniently be placed indoor or outdoor for use. For good housekeeping, the contents may be removed, the bin washed and set again for use. This type of onsite source segregation and composting waste bin is suitable for storage, segregation and composting of solid wastes at household level, as it prevents the attraction of vermin to wastes. The fabricated bin which can be made at affordable costs is quite easy to use and maintained. In addition, households can save the cost of engaging private service for their waste disposal as this bin allows for easy segregation of solid wastes at source in one device, including composting of the biodegradable materials. We recommend that the use of this bin should be adopted at household, community and institutional levels for management of solid waste, view to reducing the associated public health challenges.

**Keywords:** Composting, household solid waste, municipal waste management, recycling, waste bin, waste segregation at source, waste storage

## 1. INTRODUCTION

Waste is a global issue. If not properly dealt with, waste poses threats to both public health and the environment. It is a growing issue linked directly to the way society produces and consumes and it concerns everyone [30]. Waste is an important by-product of human activities that are mostly thrown away, because they are considered useless. All humans produce wastes of various types; for example, urine and faeces, wastes from washing and cooking, and solid wastes produced at home, workplaces, schools, hospitals and other public places [28]. Household solid waste can be defined as any unavoidable material resulting from domestic activity, for which there is no economic demand and which must be disposed of [25]. It can also be referred to as garbage and rubbish created from the day-to-day activities of living in a residential unit and does not include furniture, large rugs and household hazardous waste [7]. Household solid wastes can be grouped into two major components – decomposable refuse and non-decomposable refuse [14], [29], which can further be classified into food waste, paper, glass and other household wastes [33].

There is a growing understanding among nations of the negative impacts that solid wastes can have on the local environment (air, water, soil, human health) and also on climate change [31]. Solid waste management problem is critically serious in developing nations [1] and the streets being continually littered with the presence of solid waste from residential and commercial activities [2] as valuable habitats and biodiversity are being threatened by improper management of solid waste [31]. Out of the different categories of wastes generation, solid wastes have posed a huge problem in Nigeria [12]. The quantity and generation rate of solid wastes in Nigeria have increased tremendously over the past few years, with lack of efficient and modern technologies for management of the wastes [3]. Cities in Nigeria, being among the fastest growing cities in the world [22] are faced with the problem of solid waste management. The implication is alarming when a country is growing rapidly and the wastes generated by its citizens are not being efficiently managed. The main drivers of solid waste problems in Nigeria have been associated with poverty, high population and urbanization growth rates, compounded by a weak and underfunded infrastructure (such as inability to segregate wastes at source) [32]. Households are faced with the challenges of not having functional waste bins for storage of solid wastes that can be reused or recycled to make raw materials for industries and provide income to the waste generator when household waste is properly managed [20]. Storing of mixed wastes especially from homes, makes biodegradable materials to rot and decompose under improper, unhygienic and uncontrolled conditions [24]. When solid waste is not safely separated and stored, it can be ugly and produce intolerable odour and breeding ground for disease vectors

- Oladapo T. Okareh, T.K Ibidapo-Obe, S.A. Lateef
- Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Oyo State, Nigeria
- Email: [dapsy2001@yahoo.co.uk](mailto:dapsy2001@yahoo.co.uk)

and vermin, causing serious health problems [7], [19]. Storing food wastes with other types of wastes inhibits the proper decomposition of food wastes. Storage of mixed wastes can sometimes lead to dangerous outcomes, resulting in indiscriminate disposal, causing messy dangerous garbage dumps, blockage of drainage channels and health challenges. The main risks of bad storage to health are indirect and arise from the breeding of disease vectors, primarily flies and rats breeding in the environment [7]. Infections could also be got from mixed storage of wastes, resulting in insect and vermin encroachment, therefore causing infections in humans and making it difficult to work [11]. Bad waste disposal has been linked to poor storage, causing diseases, such as cholera, diarrhoea, dysentery, plaque, jaundice and gastro-intestinal diseases [24]. Such improper disposal can pose threats to those living in nearby communities and areas, thereby resulting in costly remediation of the environment and high burden on health [16]. Households use various methods to store wastes at home before their disposal. The waste composition and generation rate are functions of several factors that should be considered for effective waste management for environmentalists to bring about the desired solutions to the waste problems in Nigeria [3]. An important area in the management procedures of solid waste is the provision of an efficient and proper system of storage [13]. In every society, people use different traditional ways for storing and keeping waste generated from residential activities. At the household level, proper segregation of waste is required in ensuring that all organic matter is kept aside for composting, which is undoubtedly the best method for this type of waste [6]. Organic waste can be composted and then used as fertilizer, while the inorganic waste components should be recycled and reused as much as possible. The present study focuses on developing an eco-friendly waste bin for household solid waste storage and segregation, so that a major part of the biodegradable waste can be processed and used, while the non-biodegradable recyclables can be collected and recycled, reused or sold to itinerant recyclers and waste pickers. This will in no small measure encourages sorting of household solid wastes at source which will enhance easy identification of waste materials and elimination of any uncertainty as to the origin of the wastes.

## 2.0 MATERIALS AND METHODS

### 2.1 Household solid waste composition

The sampling method chosen for waste composition in this study was that used by Bernache-Perez et al. [4], which involves the direct sampling of solid waste from specific sources, a labour-intensive manual process of sorting, classifying and weighing all the items in each sampling unit and a detailed recording of the data. Simple random sampling was used to select 42 households for the household solid waste sampling. Each of the waste samples from the source of generation were emptied on a polythene sheet (1 meter square) laid on the bare floor for sorting, weighed (net weight) with Kwonnie kitchen scale (22 lbs) model 8625 and sorted into categories. The total wet weight of each waste category was determined and expressed in kilogram. The whole process of sorting and weighing was carried out five times a week (Monday to

Friday) for four weeks. Waste samples were collected from the households inside refuse bags, (where each household was given three big disposable refuse bags; paper and nylon were collected in one, plastic, glass and metals were collected in the second, while food wastes, yard trimmings and grit were collected in the third bag) were stored and assessed over a period of four weeks to obtain consistent composition. There was comparison of the results of the solid waste generation rates among Oluyole housing estate, Molete and Foko communities using mean and standard deviation. The generation rate was calculated from the formula described by Khan and Ahsan [18].

### Generation Rates =

$$\frac{\text{Total Quantity of wastes}}{\text{Number of houses} \times \text{Residents per house} \times \text{Days}}$$

### 2.2 Design and fabrication of the waste bin

The design and fabrication of waste bin was done in three phases, which included: project initiation; implementation; monitoring and evaluation. The initiation phase was the design and fabrication of the waste bin. The fabrication process was done at a local market in Ibadan. Precision and high quality was maintained in fabricating the bin. The entire volume of the bin was 3.66 m<sup>3</sup> and it was painted to add beauty and prevent rusting. The entire upper compartment was 2.44m<sup>3</sup> in volume, while the lower compartment was 1.22m<sup>3</sup>. The fabrication was done to allow for segregation of wastes. Three key elements – air, humidity, and temperature were considered in the design and construction of the lower compartment for composting. The storage bin was designed and fabricated using three galvanized steel plates of 4ft x 8ft and 2mm thickness each and folded using a 2mm radius bending roller machine. All the materials were bought at a local market in Ibadan. Before pouring the biodegradable wastes into the composting container, 2 kg of sand and 0.5Kg of sawdust were first poured to form the bottom layer which helped in maintaining moisture level for composting, to promote microbial development. The biodegradable wastes were poured into the layer containing sand and sawdust. When the composting container was about ¾ full, it was removed from the bin, separated and covered with soil and grass as covering in alternate layers to prevent loss of moisture and breeding of flies for the composting process to complete, while being turned and moistened for 28 days. The mixture were stirred every 3-day interval over a 28-day experimental period. Stirring continued for further period of 60 days to ensure full decomposition of the degraded wastes. The leachate collected from the tray at the bottom opening of the bin was continually poured back into the composting container. A garden fork was used in mixing the biodegradable waste during composting. A sharp-edged garden trowel to facilitate stirring and shredding of the wastes was used in the composting process. The stirring and shredding enhances easy access of air into the decomposing waste which is also cut to smaller pieces for easy decomposition. All the openings were closed with metal wire mesh to prevent entry of flies. The entire bin was fabricated on a two-legged stand and wheel. The various components of the bin are as shown in Plate 1. A tray was put at this bottom to collect leachate which was then poured back into the composting container. The cover of the bin was fitted with a pair of hinges that allowed the top of the

bin to be opened and closed when the bin is in use. Implementation phase involved installation of the waste bin for waste storage and segregation at source, in one selected house. Monitoring and evaluation was done by

training of the household members on its importance and usage. The compost made from food wastes at the household given the fabricated bin was collected and analysed in a laboratory.



**Plate 1: Components of the fabricated waste bin**

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Physical assessment of solid waste composition at household level

Table 1 shows the comparison of the various components of solid waste at Oluyole, Molete and Foko areas. The results revealed that food waste was the major waste generated in the three locations, with values of 48.6% at Oluyole, 39.9% at Molete and 41.3% at Foko. The high generation of food waste in the areas can be attributed to the areas being residential areas and therefore food is more

consumed in such areas. This was followed by Grit or yard waste with values of 12.8% at Oluyole, 21.0% at Molete and 19.5% at Foko, also attributed in respect of the areas being residential areas. Household sweeping, leaves dropping are major components of the grit observed. Paper, nylon, plastic, metal and glass were also generated in the areas. The waste was analysed using ANOVA to determine if there were significant differences among the various physical components of the solid waste generated daily at the three locations.

**Table 1: Comparison of various components of solid wastes at the three locations**

Parameter	Location	Mean (kg)	Percentage	S.D	P-value
Food	Oluyole	25.03	48.6	2.70	0.000
	Molete	25.96	39.9	3.32	
	Foko	183.64	41.3	11.18	
Paper	Oluyole	5.53	10.7	0.13	0.000
	Molete	6.23	9.6	0.97	
	Foko	46.41	10.4	1.88	
Nylon	Oluyole	0.70	1.4	0.20	0.000
	Molete	3.52	5.4	0.60	
	Foko	26.96	6.1	3.34	
Plastic	Oluyole	5.70	11.1	0.27	0.000
	Molete	3.54	5.4	0.87	
	Foko	38.35	8.6	7.93	
Glass	Oluyole	0.38	0.7	0.28	0.000
	Molete	0.73	1.1	0.20	
	Foko	5.15	1.2	1.15	
Metal	Oluyole	7.54	14.7	1.84	0.000
	Molete	11.43	17.6	4.56	
	Foko	57.54	12.9	1.57	
Grit	Oluyole	6.59	12.8	2.64	0.000
	Molete	13.66	21.0	1.35	
	Foko	86.70	19.5	3.22	

The findings were in consonance with the results obtained in a similar study [21], and can be attributed to the similarity in geographical location and areas of both studies. Generally, the result showed that majority of the waste generated in the areas are biodegradable waste (food and grit) compared to non-biodegradable waste (paper, nylon, plastic, glass and metal), which is in line with findings from recent similar studies [26] [10], which showed that most of the solid wastes in Ibadan are biodegradables. The results also indicate that biodegradables make higher fraction than other components of the household solid waste stream [13]. The percentage composition of the waste component was however, different from the observed non-residential areas of the University of Ibadan [9]. This is because the waste generated depended to a large extent on the nature of activities taking place, which also was revealed by the results of the study at the different residential locations. The composition was also slightly lower than that of Lagos [23], which may be attributed to the different geographical locations, different population and higher consumption of materials in Lagos, serving as factors that account for

varied waste composition [33]. Due to the high volume of food waste generated in these residential areas, they can be biodegraded and made into compost or used as animal feeds for livestock. It will therefore, be adequate for a composting facility to be established in these areas to effectively manage the food wastes. A recycling plant can also be set up to effectively manage the high amount of recyclables generated in the areas.

#### 3.2 Determination of the generation rate of solid waste at household level

Waste generation rate in the three areas was assessed during this study. Waste generation rate at Foko was highest with an estimated mean rate of 0.60kg/person/day and lowest at Oluyole with mean rate of 0.45kg / household / day, while Molete had an estimated mean rate of 0.57kg/household/day as shown in Table 2. The high generation rate obtained at Foko could be as a result of the low socio-economic class they belong to.

**Table 2: Mean waste generation kg/household/day in the three locations**

Location	Week 1	Week 2	Week 3	Week 4	Mean
Oluyole	0.51	0.44	0.47	0.37	0.45
Molete	0.52	0.54	0.61	0.59	0.57
Foko	0.59	0.58	0.61	0.64	0.60

*Population used (Households) in Oluyole – 5; Molete – 5; Foko – 32*

The findings from this result of waste generation is similar to the values of 0.4 kg/household/day to 0.6 kg/household/day given by [3], [5], and [15] for developing cities and countries. This could be attributed to the fact that the areas are residential areas and therefore goods and products are highly consumed as people spend lots of time in these areas. The variation of the generation rates among the three locations supports [27], that quantities and categories of solid waste generation also varies with socio-economic groups in which the high and middle residential area groups take the bigger share. The study was however different from finding of [9], which can be attributed to the areas not being residential areas. Because of the high values of waste generation rates in these areas, the wastes would be adequate enough to provide materials to both homes and industries for use if they are managed efficiently. These high generation rates therefore make it essential for waste recycling facilities to be established in these areas, as viable means to manage the problems of waste in the areas.

### 3.3 Testing of fabricated waste bin for household solid waste storage, segregation and composting of biodegradable wastes.

The bin designed for storing and segregating household wastes at source can be seen in plate 2, with its labelled parts comprising “paper”, “plastic” and “glass” for the upper compartment and “food waste” at the lower compartment (plate 2A). At the upper compartment, three boxes were made for separating the non-biodegradable wastes, while the lower compartment allowed for storage and composting of biodegradable wastes (plate 2B). The materials in upper compartment which can be put include: paper (which includes news prints, magazines, shopping paper bags and all forms of material manufactured from the pulp of wood); plastic (which include PET, PP, PVC bottles, nylons and all forms of synthetic material made from a wide range of organic polymers that can be moulded into shape while soft); metal (which include glasses, cans, tins and all hard, brittle materials); organics (which include food waste, grit from sweeping or tree droppings and all other forms of biodegradable materials).



**Plate 2: Waste bin for segregating, storing and composting of household wastes. (A: Labeled components of the waste bin; paper, plastic, glass, organic. B: Testing of the components for segregation of wastes. C: Compost made from household biodegradable wastes)**

General household solid wastes were stored and segregated in the bin as shown in Plate 2B. Food residuals were also collected daily from the randomly selected household and were put into the bin. They were stirred every 3-day interval over the 28-day experimental period. Stirring continued for further period of 60 days so as to ensure full decomposition of the degraded wastes. The leachate collected from the bottom opening of the bin was continually poured back into the "cooking" compost. At the end of the test period, about 13 weeks, the household biodegradable waste was converted to golden brown organic fertilizer (Plate 2C). Analysis of the compost revealed a pH value of 9.28, nitrogen of 0.82%, organic carbon of 7.86%, potassium level of 43.61 cmol/kg and available phosphorus 317.65 mg/g, showing its suitability for both household gardening and farmland fertilizer. The bin fabricated is quite easy to use and can be made at an affordable costs. It is easy to maintain. For improved good housekeeping, the contents may be removed, the bin washed and set again for use. The time required for compost formation depends on the nature of the waste, the amount, and the ambient temperature. The bin can be conveniently placed at the backyard close to the kitchen and could be handy for housewife's uses. Smell and fly nuisance commonly associated with other waste bins were averted through the use of regular monitoring of the contents and processes. More than these benefits, households could save the cost of engaging private service for their waste disposal as it allows for onsite recycling of waste materials. Most interesting, households interacted with in the course of this study are already showing interest in using the fabricated bin.

#### 4. CONCLUSION AND RECOMMENDATIONS

An exploratory study was done to design and fabricate an eco-friendly bin for household solid waste storage, segregation and composting of the biodegradable wastes. The enhanced capability of the designed bin for management of biodegradable and non-biodegradable wastes at household level has been demonstrated in this study. The study has shown that the designed bin could store both biodegradable and non-biodegradable wastes for 28 days without associated problems of waste storage. The results of the study also suggest that the bin could be a reliable and affordable option for management of solid waste at both community and institutional levels. It is therefore recommended that in order to save cost on engaging the services of private waste collector for waste disposal and to reduce the associated public health challenges, the use of this bin should be adopted at household, community and institutional levels for management of solid waste.

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