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COST BENEFIT ANALYSIS OF COMPOSTING AS A WASTE MANAGEMENT STRATEGY IN LAGOS STATE SOUTHWESTERN NIGERIA.

Chika Floyd **Amaechi** [1*] & Phebean Oshuare **Omaivboje** [1]

[1] Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, PMB 1154, Benin City, Nigeria.

***Corresponding author**: chika.amaechi@uniben.edu

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Abstract

Purpose — This study assessed the viability of composting as a waste management tool.
Methods — This study assessed waste production and handling in Lagos State and adapted a case study of cost-benefit analysis to ascertain viability.
Findings — Results from the study revealed that one hundred and forty-one billion, one hundred and sixty-one million, and six hundred thousand naira (₦141,161,600,000.00) equivalent to three hundred and twenty-three million, two hundred and sixteen thousand, five hundred and fifty-nine dollars ($323,216,559.05) would be generated as profit per annum if the total waste produced in Lagos State daily is converted to compost.
Conclusion & Recommendation — This study recommends composting as the best waste management strategy in Lagos State and Nigeria due to its financial, environmental, health, and agricultural benefits.

Keywords — Cost-benefit analysis, Compost, Waste Management, Lagos, Nigeria.

Introduction

Over the years, the inefficient management of solid waste has been an issue of concern in Africa and the world at large. The amount of municipal solid waste (MSW) in Nigeria, in particular, has steadily increased as a result of population growth, urbanization, and industrialization (Imam et al., 2008). Currently, the Nigerian population has exceeded 200 million (Macrotrends, 2022) and has been tagged as one of the largest producers of solid waste in Africa (Bakare, 2021). Although there are a host of policies and regulations guiding solid waste management in the country, the quantity of waste produced daily is at an alarming rate (Bakare, 2021). The municipal solid waste generation rate in Nigeria is estimated to be 0.65-0.95 kg per capita per day, resulting in an average of 42 million tonnes of waste generated annually, while organic waste produced annually in Nigeria is 23,520,000 tonnes (56% of wastes generated are organic wastes), which can be turned into compost to enrich Nigeria by billions of naira (Zulkepli et al., 2017).

The environment is generally affected by waste, leading to disease outbreaks, a reduction in life expectancy, and unsafe environments. While some wastes may rot, smell, and generate methane gas and other greenhouse gases, others do not rot but lead to water and soil pollution (Ayilara et al., 2020). In response to this and other global environmental concerns, it has been concluded that composting is an environmentally

friendly and economically viable waste management strategy that can be adopted while discouraging landfilling (Beatti andS Alicia, 2014; Zulkepli et al., 2017).

According to Ayilara et al., composting involves the biological process of decomposition of organic waste, whereby organic waste is made into a usable product called compost. The conversion process of turning degradable organic wastes into stable products with the aid of microorganisms is done under controlled conditions (Ayilara et al., 2020). Categorically, composting can be broadly divided into aerobic and anaerobic composting (Keng et al., 2020). Aerobic composting is done in the presence of oxygen, leading to the conversion of organic solid waste into compost, a beneficial material used to improve the quality of soil and provide plants with their required nutrients (Al-Rumaihi et al., 2020). Aerobic composting can be carried out in two ways: open-system aerobic composting or closed-system aerobic composting. The open system includes the aerated pile and windrow processes, while the closed system includes in-vessel or container systems (Keng et al., 2020). Anaerobic composting technology, on the other hand, operates in an oxygen-free environment, such as the Bokashi approach that uses inoculated bran to transform organic waste into compost through fermentation (Keng et al., 2020).

Municipal solid waste management has always been a source of concern in every society. With the most common waste management strategy being landfilling, the practice of landfilling poses several threats, both to humans and the environment. For instance, landfill sites are susceptible to open burning, which pollutes the air and thereby releases methane and carbon dioxide, which are major greenhouse gases, through the anaerobic decomposition of waste (Hegde et al., 2003). People living close to dumpsites are exposed to disease vectors and suffer from various diseases such as cholera, diarrhea, and malaria (Sankoh et al., 2013). This study emphasizes the costs and benefits of composting as a sustainable waste management strategy. Cost-benefit analysis is an environmental management tool used to evaluate the cost-effectiveness.

Due to the associated environmental and health impacts, landfill waste disposal is the least desirable option for effective waste management from a sustainability perspective. As previously stated, 56% of all waste produced in Lagos is organic waste. In practice, composting plants can use these organic wastes as raw materials to produce compost. World Bank reported that Over 50% of the waste in developing countries is organic, which has the potential to be used for regenerative processes such as composting to improve soil conditions, job creation, etc. if it is managed properly (World Bank Report on Global Solid Waste Management, 2012).

A study carried out by Khan et al., (2022) revealed that organic waste has high potential for composting when evaluated and converting waste to compost becomes more profitable as well as sustainable when compared to landfill disposal. Despite the apparent advantages of converting waste to compost, Lagos State still engages in landfilling as waste management strategy of its huge amounts of waste (Chidi et al., 2021), this may be as a result of inadequate knowledge surrounding the costs and benefits of composting. This study therefore seeks to assess the costs and benefits of composting of organic waste as against the practice of landfilling in Lagos State to determine its economic viability.

Materials and Methods

Study Area

The area selected for this study is Lagos state, Southwestern Nigeria. The Lagos metropolitan area is situated within latitudes N06° 23’ and N06° 40’ and longitudes E03° 13’ and E03° 27’. The megacity of Lagos State has an estimated population of 24 million and about 13,000 tonnes of solid waste is generated daily (Chidi et al., 2021). The Lagos state waste management authority (LAWMA) disposes off about 7,000 tonnes of solid waste daily in the 3 major landfill sites across the state. There are 3 major landfill sites serving the Lagos metropolitan area which are Abule Egba, Igando and Olushosun landfills.

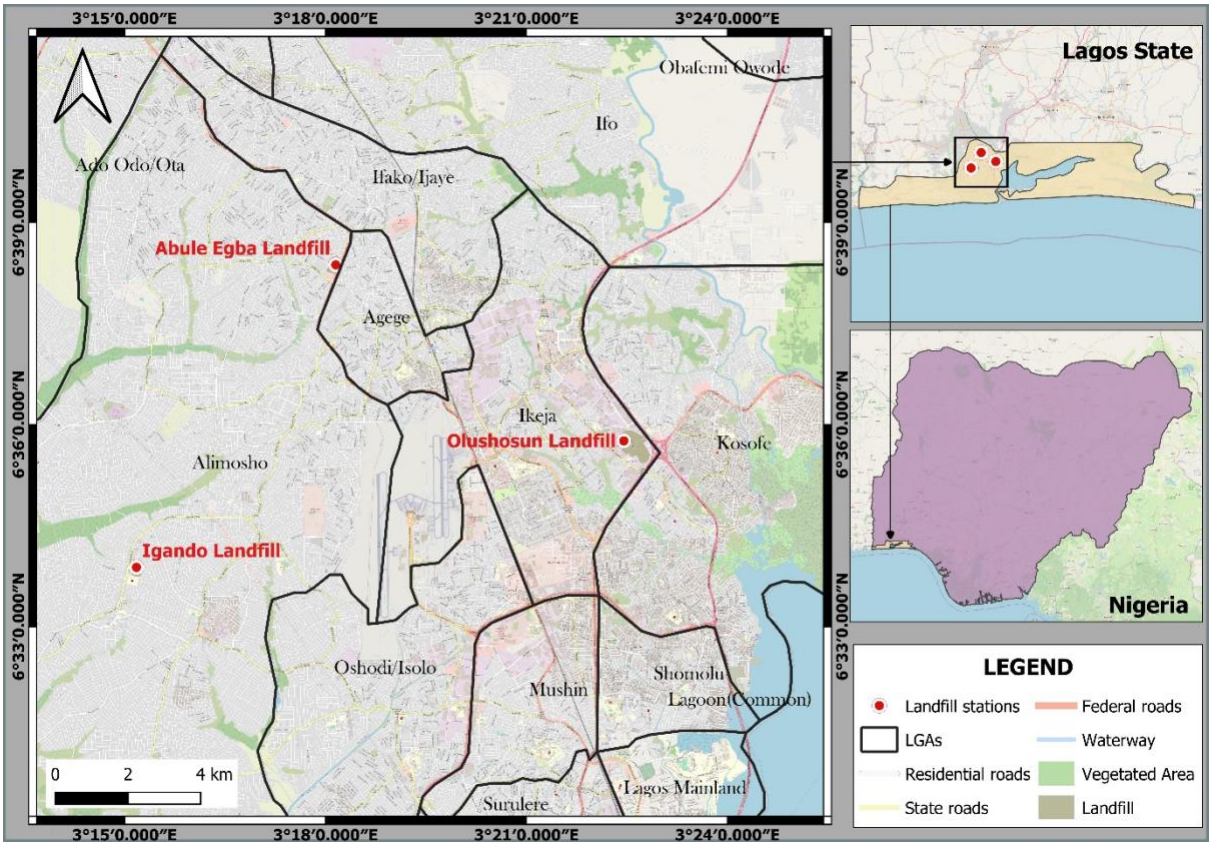

Figure 1: Geological map of Lagos showing the location of the three major landfills of study

Data Sources

This study relied primarily on secondary data, which was sought and reviewed. In other to achieve the aim of this study the researchers adapted data from a study carried out by Ali et al., (2013) on cost comparison of constructing a standardize composting facility and a biogas facility as well as another study carried by Zulkepli et al., (2017) on waste management generation which revealed that 56% of municipal solid wastes generated in Lagos State are organic and can be potentially used for compost. Table 1-4 were collected and reviewed to determine relevant literatures on waste management and to also appraise the current state of solid waste management in Nigeria, while identifying cost- benefit as a suitable concept to analyze composting as a sustainable waste management strategy.

For the satellite images, existing google imageries of the study areas was downloaded from the Google Earth with radiometric resolution of 10m. Coordinates of different locations in the study area was also obtained by the use of Global Positioning System (GPS).

Method of Data Analysis

A cost-benefit analysis (CBA) is performed to evaluate the situation of data verification. This is a method widely used in different management studies for decision making (Ali et al., 2013) but its application is very rare in compost related studies in Nigeria. The following formulas were used for analysis:

Cost Benefit = Total benefits - Total cost …….. .. (Equation 1)

The Benefit-cost Ratio (BCR) is calculated as the total benefits divided by the total costs:

$$BCR = \frac{\sum_{r=1}^{r} B_t / (1+r)^2}{\sum_{r=1}^{r} C_t / (1+r)^2}$$

…… (Equation. 2)

Where B = Benefit

r = rate of discount

C = Cost

The return period for investment cost was also calculated using the following method:

Return period for investment cost = Investment cost / Return Benefit. ... (Equation 3)

Case Study Adapted for the Study

As cited by Ali et al., (2013), the cost-benefit of composting was carried out in Thailand using the model below.

Table 1: Estimate of compost plant construction and operation in Thailand

Investment *Cost		**Operation and Maintenance Cost (Thai baht (THB)**			**Benefits**
Construction	1,000,000.00	Unit cost per ton	3,200.00	Unit cost per ton	10,000.00
Working capital & contingency	1,500,000.00	Total waste quantity (tonnes)	14.4	Total compost quantity (tonnes)	8.1
Process equipment & machinery	1,000,000.00	Total cost per day	46,080.00	Total income per day	81,000.00
**Fees	500,000.00	Total cost per annum	**16,819,200.00**	Total benefits per annum	**29,565,000.00**
Total	**4,000,000.00**				

Source: Adapted from Ali et al., (2013)

Table 2: Detailed estimation and analysis for compost plant in Thailand

Benefits and costs	Estimations	Total
Total cost of compost per annum	THB 16,819,200.00	-
Total benefits from savings and compost production	803,000.00 + 29,565,000.00	THB 30,368,000.00
Gross return per annum = Total benefits – Total costs	30,368,000.00 – 16,819,200.00	THB 13,548,800.00
BCR = Total benefits/Total costs	13,548,800.00/16,819,200.00	0.80
Investment cost for compost plant	THB 4,000,000.00	-
Return period for investment cost	4,000,000.00/30,368,000.00	~1 years

Source: Adapted from Ali et al., (2013)

Table 3: Estimate of compost plant construction and operation in Lagos.

Investment * cost		**Operation and Maintenance Cost**		**Benefits**	
Construction	12,400,000.00 ($28,392.18)	Unit cost per ton	39,680.00 ($90.86)	Unit cost per ton	124,000.00 ($283.92)
Working capital & contingency	18,600,000.00 ($42,588.27)	Total waste quantity (tonnes)	14.4	Total compost quantity (tonnes)	8.1
Process equipment & machinery	12,400,000.00 ($28,392.18)	Total cost per day	571,392.00 ($1,308.31)	Total income per day	1,004,400.00 ($2,299.76)
**Fees	6,200,000.00 ($14,196.09)	Total cost per annum	208,558,080.00 ($477,533.73)	Total benefits per annum	366,606,000.00 ($839,414.76)
Total	49,600,000.00 ($113,568.71)				

Source: Adapted from Ali et al., (2013)

Table 4: Detailed estimation and analysis for compost plant.

Benefits and costs	Estimations	Total
Total cost of compost per annum	₦208,558,080.00 ($477,533.73)	₦208,558,080.00 ($477,533.73)
Total benefits from compost production	₦ 366,606,000.00 ($839,414.76)	₦366,606,000.00 ($839,414.76)
Gross return per annum = Total benefits – Total costs	₦366,606,000.00 - ₦208,556,080.00	₦158,049,920.00 ($361,885.61)
BCR = Total benefits/Total costs	₦158,049,920.00/ ₦208,556,080.00	0.76
Investment cost for compost plant	₦49,600,000.00 ($113,568.71)	-

Source: Adapted from Ali et al., (2013)

Results and Discussion

Cost Benefit Analysis

The collection and disposal of waste which is the current solid waste practice in Lagos state is handled by the Lagos state Waste Management Agency (LAWMA) and it accounts for only about 55% of the total waste produced daily. The remaining 45% is transported to illegal dumpsites by the residents.

Consequently, analysis in this study will be done in the two different scenarios;

Total waste produced in Lagos state daily = 13,000 metric tonnes

Total waste collected by LAWMA daily = 7,000 metric tonnes.

Scenario 1: C.B.A for the total waste produced in Lagos State

Results per day for scenario 1

Total waste produced in Lagos State daily = 13,000 metric tonnes

From the case study adopted, it can be deduced that a single composting plant can only process 14.4tonnes of waste at a time.

Operation and Maintenance Cost

From table 3, the operation and maintenance cost incurred to process a ton of waste to become compost (unit cost per ton)

Unit cost per ton = ₦39,680.00 ($90.86).

For a single composting plant, the cost of processing 14.4tonnes of waste in a day to give 8.1 tonnes of compost is;

Cost for processing 14.4tonnes =14.4 x ₦39,680.00 ($90.86)

= ₦571,392.00 ($1,308.31)

Therefore, the total cost incurred in processing the total waste produced in Lagos state daily (13,000 tonnes) to become compost is;

Total waste x 39,680.00 ($90.86)

Cost for processing 13,000 tonnes = 13,000 x ₦39,680.00 = ₦515,840,000.00 ($1,181,114.62)

Benefits

Table 3 shows that only about 56% of solid waste is turned to compost (56% of 14.4= 8.1) Therefore, the amount of compost derived from 13,000 tonnes of waste

= 56% of 13,000 tonnes

= 7,280 tonnes
From Table 3, the benefit derived from selling a single ton of compost (unit price per ton)
Unit price per ton = ₦124,000.00 ($283.92).
For a single composting plant that can achieve 8.1tonnes of compost from 14.4tonnes of waste, the benefit is;
Cost of selling 8.1 tonnes of compost = 8.1 x ₦124,000.00 ($283.92) = ₦1,004,400.00 ($2,299.76).
Therefore, the total amount that will be benefited from selling the compost derived from the total waste produced in Lagos state daily (7,280 tonnes of compost)
= 7,280 X ₦124,000.00 ($2,299.76)
Cost of selling 7,280 tonnes of compost = ₦902,720,000.00 ($2,066,950.60)

Cost-Benefit Analysis for scenario 1 per day
C.B.A for a day = Benefit - cost
₦902,720,000.00 ($2,066,950.60) – ₦515,840,000.00 ($1,181,114.62)
= ₦ 386,880,000.00 ($885,835.97).
Results per annum for scenario 1: Cost per annum = Cost per day x 365
= ₦515,840,000.00 x 365
Cost per annum = ₦ 188,281,600,000.00 ($431,106,837.02)

Total Cost
Total cost = Investment Cost + Cost per annum
= ₦49,600,000.00 ($113,568.71) + ₦188,281,600,000.00 ($431,106,837.02)
Total cost = ₦188,331,200,000.00 ($431,220,405.73)
Benefit Per Annum = Benefit per day x 365
= ₦902,720,000.00 ($2,066,950.60) x 365
= ₦329,492,800,000.00 ($754,436,964.98)
C.B.A for the year = Benefit per annum — Total Cost
= ₦329,492,800,000.00 ($2,066,950.60) — ₦188,331,200,000.00 ($431,220,405.73)
= ₦141,161,600,000.00 ($323,216,559.05)
Benefit – Cost Ratio (BCR)
= 1.75: 1 approximately 2:1
Return Period for Investment
Return period for investment = Total cost / Benefit per annum
= ₦188,331,200,000.00 ($431,220,405.73) / ₦329,492,800,000.00 ($2,066,950.60)
= 0.6 year
Return period for investment = 7.5 months
Scenario 2: for waste collected by LAWMA in Lagos State
Results per day for scenario 2
Amount of waste collected by LAWMA daily = 7,000 metric tonnes.
From the case study adopted, it can be deduced that a single composting plant can only process 14.4tonnes of waste at a time.

Operation and Maintenance Cost
From Table 3, the operation and maintenance cost incurred to process a single ton of waste to become compost (unit cost per ton) = ₦39,680:00 ($90.86).
For a single composting plant, the cost of processing 14.4tonnes of waste daily to give 8.1 tonnes of compost is;
Cost for processing 14.4 tonnes =14.4 x ₦39,680.00 ($90.86)
= ₦571,392.00 ($1,308.31).
Therefore, the cost incurred in processing the actual amount of waste collected by LAWMA daily (7,000 tonnes) to become compost is equal to Waste collected x ₦39,680.00 ($90.86).
Cost for processing 7,000tonnes = 7,000 x ₦39,680.00 ($90.86) = ₦277,760,000.00 ($635,984.79).
Benefits

It can be seen from Table 3 that only about 56% of solid waste is turned to compost (56% of 14.4= 8.1). Therefore, the amount of compost gotten from 7,000 tonnes of waste
= 56% of 7,000 tonnes
= 3,920 tonnes
From Table 3, the benefit derived from selling a single ton of compost (unit price per ton)\
Unit price per ton = ₦124,000.00 ($2,299.76)
For a single composting plant that can achieve 8.1tonnes of compost from 14.4tonnes of waste, the benefit is;
Price for selling 8.1tonnes of compost =8.1 x ₦124,000.00 ($2,299.76)
= ₦1,004,400.00 ($2,299.76).
Therefore, the total amount that will be benefited from selling the compost gotten from the actual waste collected by LAWMA daily (3,920 tonnes of compost)
= 3,920 x ₦124,000.00 ($2,299.76).
Price for selling 3,920 tonnes of compost = ₦486,080,000.00 ($1,112,937.39).

Cost-Benefit Analysis for scenario 2 per day
C.B.A for a day = Benefit - cost
= ₦486,080,000.00 ($1,112,937.39) – ₦277,760,000.00 ($635,984.79).
C.B.A for a day = ₦ 208,320,000.00 ($476,988.60).
Results per annum for scenario 2:
Cost per annum = Cost per day x 365
= ₦277,760,000.00 ($635,984.79) x 365
Cost per annum = ₦101,382,400,000.00 ($232,134,450.70)

Total Cost
Total Cost = investment cost + cost per annum
=49,600,000.00 ($113,568.71) + ₦101,382,400,000.00 ($232,134,450.70)
Total Cost =₦101, 432, 000,000.00 ($232,248,019.42)
Benefit Per Annum
Benefit per annum = Benefit per day x 365
= ₦486,080,000.00 ($1,112,937.39) x 365
Benefit per annum =₦ 177,419,200,000.00 ($406,235,288.73).
C.B.A for The Year = Benefit per annum — Total cost
= ₦177,419,200,000.00 ($406,235,288.73) — ₦101, 432, 000,000.00 ($232,248,019.42)
= ₦75,987, 200,000.00 ($173,987,269.31)
Benefit – Cost Ratio (BCR)
= 1.75: 1 approximately 2:1
Return Period for Investment
Return period for investment = Total cost / Benefit per annum
=₦101, 432, 000:00, 000.00 ($232,248,019.42) / ₦177,419,200,000.00 ($406,235,288.73)
= 0.6 year
Return period for investment = 7.5 months

Discussion
The cost-benefit analysis of composting the total waste produced in Lagos State and the actual waste collected by the Lagos State Waste Management Authority shows that converting waste to compost will generate huge revenue for the state and reduce the amount of waste that will be disposed of in landfills (Otoo and Hanjra, 2018). The result of this study supports earlier claims made by Otoo and Hanjra in their book titled "Large scale composting for revenue generation" that several revenue streams can be generated through large-scale composting, including sales of compost, which is the largest revenue stream (Otoo and Hanjra, 2018).
As seen in this study, if the amount of waste collected by LAWMA on a daily basis is converted to compost, the sum of Seventy-Five Billion, Nine Hundred and Eighty-Seven Million, Two Hundred Thousand Naira (₦75,987,200,000.00) which is equivalent to One Hundred and Seventy-Three Million, Nine Hundred and

Eighty-Seven Thousand, Two hundred and Sixty-Nine Dollars ($173,987,269.00) would be generated as profit annually. However, if the total amount of waste produced in Lagos State is converted to compost, the profit realized at the end of the year would be One Hundred and Forty-One Billion, One Hundred and Sixty-One Million, and Six Hundred Thousand Naira only (₦141,161,600,000.00), which is equivalent to Three Hundred and Twenty-Three Million, Two Hundred and Sixteen Thousand, Five Hundred and Fifty-Six Dollars ($323,216,559.00), and this is without the multiplier effect of job creation, reduced environmental and health risks and increased agricultural input resulting in greater crop yield.

From this study, it's clear that composting is a sustainable and efficient tool for solid waste management compared to landfilling as it generates wealth and health for all. Also, Zulkeplia et al., (2017) opined that composting is the most environmentally friendly way to deal with trash compared to other methods like putting trash in landfills. In the same way, Rominger explained in his 2020 study that composting turns waste that would have been thrown away into a very valuable resource, reducing the amount of trash that ends up in landfills (Rominger, 2020).

In addition, implementing composting as a sustainable solid waste management strategy in Lagos State would not only minimize the waste burden of the state but would be an example for the rest of the states in Nigeria and other African countries having similar issues with waste management. As a result, it is safe to conclude that composting is one of the best ways for Lagos State and Nigeria, in general, to deal with solid waste.

Conclusion and recommendation

The study demonstrated that composting can reduce organic waste in landfills and produce value-added products. Based on this study's cost-benefit analyses, composting is one of the best ways for Lagos State and Nigeria at large to solve the solid waste management problem and provide the greatest financial, health, and environmental benefits. It is therefore recommended to adopt composting as an environmentally friendly method for waste management.

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