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# Evaluation of the University of Lagos Waste Generation Trend †

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**Abstract:** This study examines waste generation patterns at the University of Lagos (UoL), Nigeria, to inform decision-making towards improving the efficiency of the university's management strategies in line with Sustainable Development Goal 12, target 12.5 to reduce waste generation through prevention, reduction, recycling, and reuse by 2030. The moving average of the waste generation was studied using time series data. During October 2014 to October 2016 the UoL generated an average of 877.5 tons of waste every month, with the lowest observed value being 496.6 tons and the highest recorded value being 1250.5 tons. The trend result indicates a gradual decrease in the generation of waste over time. There is also a noticeable negative cyclical pattern with seasonal variations, where the highest generation point is observed in March and the lowest point is observed in June, particularly in the latter half of the second quarter, as time progresses. Although there is a reduction in the amount of waste generated over time, it is crucial to persist in evaluating diverse waste management strategies that could further reduce the amount of waste generated in the case study area.

**Keywords:** sustainable waste management; waste trend; moving average

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## 1. Introduction

In recent decades there has been a push for sustainable waste management, with governments implementing waste legislation to handle the growing amount of waste generated and protect limited natural resources [1–3]. Often, such legislation leads to recycling campaigns, a sustainable waste management strategy aiming to reduce virgin resource use. Efficient recycling process, combined with waste reduction and reuse, is essential for achieving sustainability [2,4,5]. A strategy published by the Government of Nigeria, i.e., the Solid Waste Management Policy Guideline (NSWMPG), aims to effectively manage waste in a way that supports sustainable practice, thereby reducing any negative environmental and public health effects caused by waste generation and disposal [6].

Waste characterization has been employed in academic research to support the implementation of such sustainable waste management strategies [7]. Characterization entails the identification of recoverable materials and the establishment of targets to reduce the amount of waste, including biodegradable waste, that is disposed of in landfills, which aids in reducing potential problems related to waste disposal [8–12]. The current emphasis in research studies is mostly on characterizing municipal solid waste (MSW), with a particular focus on analyzing waste composition at the home level. However, understanding waste generation trends is critical to developing appropriate management plans and strategic treatment approaches to deploy in managing such waste effectively in line with Sustainable Development Goal 12, target 12.5 to reduce waste generation through prevention, reduction, recycling, and reuse by 2030. Higher education institutions (HEIs), which can have a significant impact on promoting the development of a sustainable society, face

similar difficulties as municipalities in waste management; hence, it would be beneficial to understand waste generation and characterization in HEIs in addition to households. HEIs can be compared to urban areas like towns and cities, as they generate a substantial amount of solid waste due to their large and diverse population and range of activities undertaken [12–15]. Some studies have examined the composition of waste generated and the effectiveness of recycling to improve sustainable waste management at HEIs. Adeniran et al. [16] and Mbama et al. [17] conducted studies on compositional analysis and waste recycling efficiency, respectively, at the University of Lagos. These studies did not evaluate the waste generation trend which is crucial for effective waste management planning and achieving sustainability [18].

The aim of this research was to evaluate the waste generation trends at the University of Lagos. This will help to understand the environmental impact of waste and provide valuable insights into the potential patterns of waste generation, enabling informed decision-making and appropriate budget allocation for effective planning.

## 2. Methodology

### 2.1. Study Area and Data Collection Process

The University of Lagos (UoL) is one of Nigeria's oldest universities and institutes of higher learning, with its establishment dating back to 1962. Mbama et al. [17] reported that the institution, with a daily population of approximately 87,000, generates an average of 32.2 tons of waste each day. The main campus in Akoka, in the western region of Lagos State, is divided into four distinct zones, labelled A–D (Figure 1); each zone contains administrative, commercial, and residential areas. The activities conducted in the administrative areas encompass both academic work and administrative office tasks. The commercial areas encompass various market venues, including restaurants, parking lots, places of worship, and copier shops. While within the residential areas, many activities occur, such as the presence of staff quarters and student dorms. The variety of ongoing on-campus activities result in the generation of a diverse range of waste types, but primarily similar in composition to municipal solid waste.

The university's waste management is overseen by the Department of Works and Physical Planning (DWPP). The DWPP has engaged and monitors the services of two private waste contractors to manage the waste generated by the institution. The UoL's waste management policy published in 2014 ushered in more sustainable strategies including the introduction of color-coded waste bins for waste segregation. However, the waste is still collected and deposited at the university's recycling facility, where the contractors manually sort the recyclable materials into their appropriate streams, e.g., paper, plastic, etc.

In September 2016, an email was sent to the DWPP, marking the initial point of contact with the institution to seek approval to visit and undertake research in December of the same year. Prior to undertaking any research, a formal presentation was made to the UoL to explain the study and acquire permission to conduct research on the campus. During the presentation, the researcher (C.A.M.) posed structured questions to the DWPP to gain an understanding of the institutions' approach to waste management. A request for the provision of waste generation data for the period 2006–2016 was also lodged. In addition to the formal presentation, members of the cleaning team and drivers for the waste collection service were engaged in informal discussion on waste management practices. The University provided waste generation data, which encompassed the period from October 2014 to October 2016. An examination of trends was conducted using the time series moving average in Excel to discover the underlying pattern within the time series data. The moving average approach is a statistical technique used to reduce variability in data, allowing for the detection and highlighting of important trends or patterns [19,20].

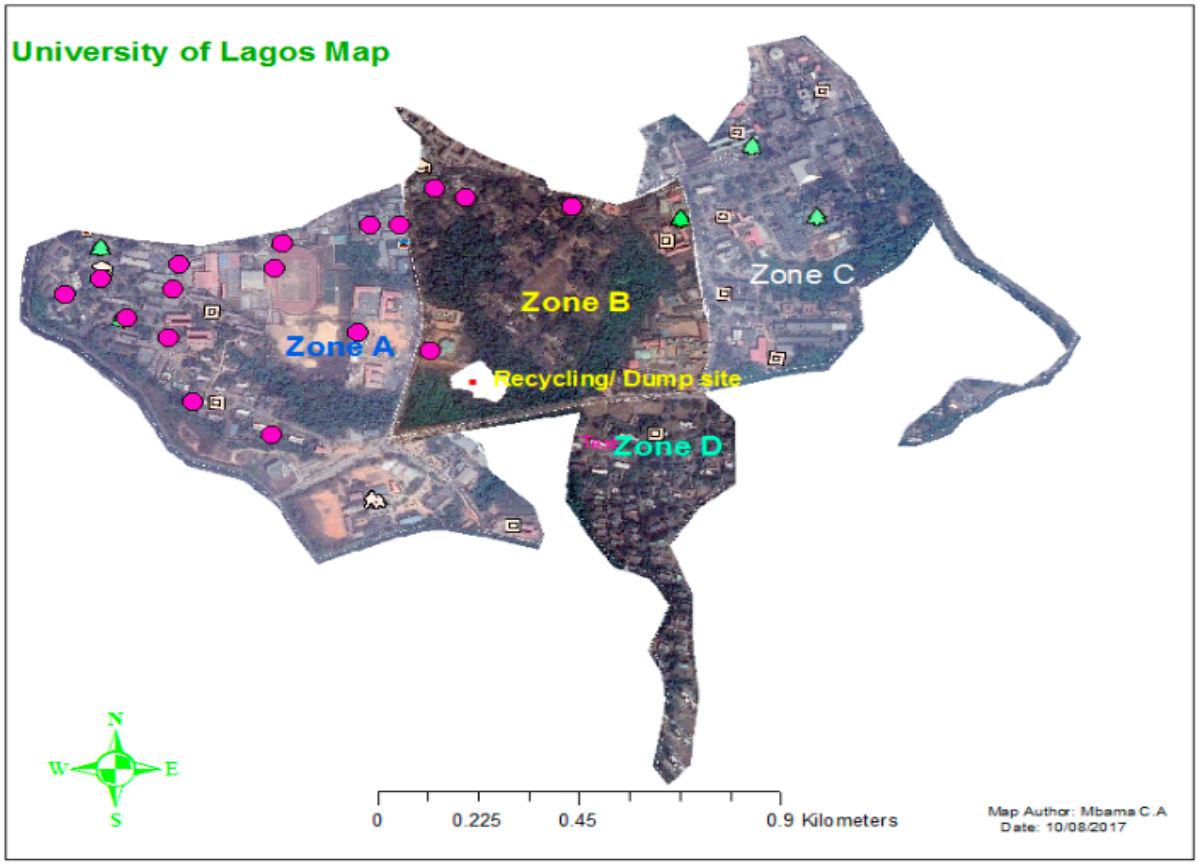


**Figure 1.** Map of University of Lagos, Akoka Campus, showing the location of the four campus zones (A–D) (source: Mbama et al., 2023 [17]).

### *2.2. Time Series Methodology*

Utilizing the moving average method, the waste data was examined using time series analysis. This approach offers a valuable methodological contribution to understanding the complex nature of data management, particularly in identifying long-lasting trends and patterns [21–23]. One important aspect of the moving average in a management plan is its ability to smooth data over time, which helps to minimize the effects of short-term fluctuations [23–26]. The purpose of this evaluation was to get a more in-depth understanding of the capacity and trajectory of waste generation and understanding the impact of seasonal variations and irregularities in waste generation, as this knowledge is crucial in the field of waste management. Through a deep understanding of these patterns, waste management authorities can make informed decisions regarding infrastructure design, resource allocation, and recycling initiatives.

## 3. Results

### *Solid Waste Management*

The waste management data and procedures at the UoL were obtained from the DWPP through personal correspondence. The department maintains detailed records regarding various waste management activities, including daily waste generation, recycling rates, disposal rates, and other pertinent information pertaining to waste management. In addition, the department oversees the actions of waste contractors to guarantee the appropriate recovery of recyclable waste and safe disposal of waste too, thus minimizing any hazards to the general population. The UoL's solid waste data for the years 2014–2016 are shown in Figure 2.

The UoL generates an average of 877.5 tons of waste every month, with the lowest recorded amount being 496.6 tons (October 2014) and the largest recorded amount being 1250.5 tons (March 2015). The moving average analysis indicates the existence of a noticeable seasonal pattern in the dataset, as can be seen in Figure 2. After conducting an analysis of the time series and trend at the University of Lagos (UoL), it has become abundantly clear that there is still a recurrent pattern in the generation of waste. There is a discernible pattern of recurrent negative cycles that exhibit seasonal fluctuations. The peak of this pattern is noticed in the month of March, which coincides with the first three months of the year. The month of June, and more specifically the latter half of the second quarter, is the month that achieves the lowest point as time progresses. The projection has the ability to extend to the generation for the year 2017, with the expectation that it will exhibit a pattern that is repeated.

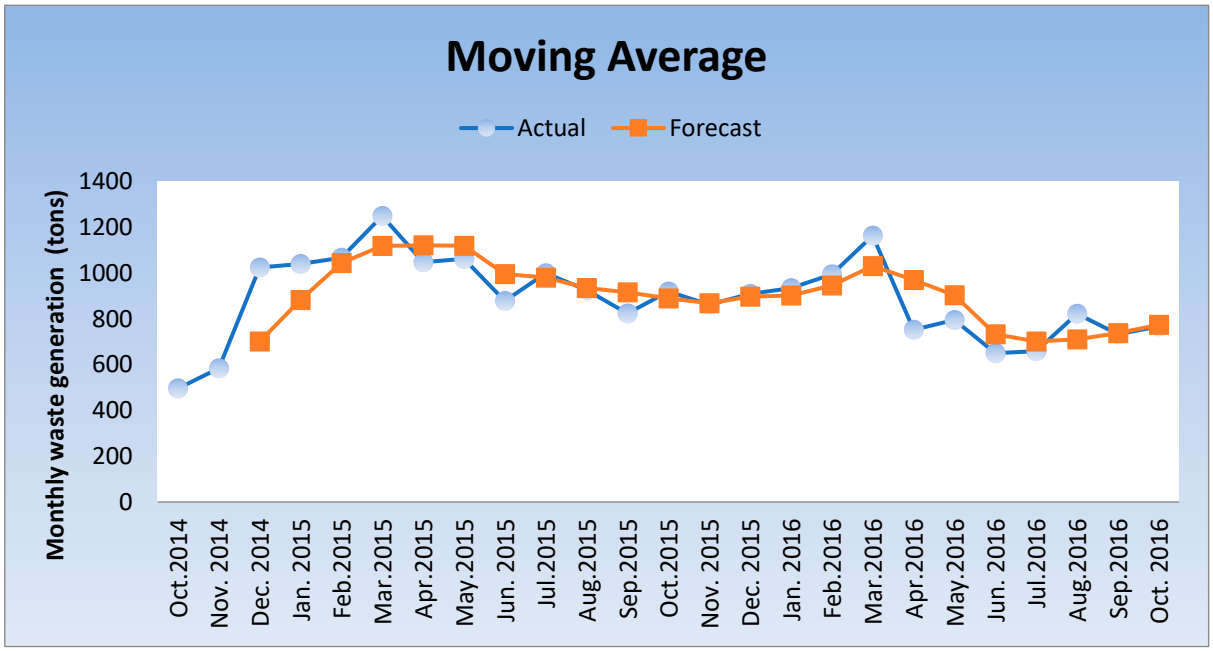


**Figure 2.** Monthly waste generation and moving average forecasting the trend from October 2014 to October 2016 in the Akoka Campus, University of Lagos.

## 4. Discussion

In line with the waste management policy announced in 2014, the UoL implemented a recycling scheme to help manage their waste more sustainably. This scheme involved the distribution of more than 800 color-coded waste bins throughout the campus. The bins were assigned for the collection of different waste materials; for example, blue bins were designated for mixed paper, green bins for mixed plastic, red bins for cans, and black bins for general waste disposal, as detailed by Mbama et al. [17]. Although the institution has made progress in waste infrastructure, such as setting up a recycling center (where waste is sorted), providing color-coded waste containers, and introducing haulage trucks for waste transportation, it still faces challenges. A major challenge is the lack of a comprehensive waste management system that effectively considers the economic and environmental benefits of the waste generated [17]. However, to be able to do this there needs to be understanding of current trends and patterns in waste generation to enable efficient planning and allocation of adequate resources for optimal management.

### *Temporal Waste Generation Pattern*

Through application of the moving average, a comprehensive analysis was conducted to highlight the waste generation capacity and gain insights into the waste generation

patterns within the university setting. The approach mentioned above has been utilized by many researchers to gain insights into waste patterns [19,24,27,28]. Based on the analysis conducted at the UoL, it is evident that there is a noticeable cyclic pattern in waste generation. The result also showed a gradual decrease in waste generation over time. It is likely that this decrease is a consequence of the waste minimization campaigns implemented by the university after the introduction of their waste management policy in 2014.

The cyclical pattern shows the highest level of generation is typically observed between the months of March and May, whereas the lowest level is typically seen in July. This can be explained by the fact that university activities tend to vary depending on the academic calendar. During times when student activities decrease, there is typically a corresponding decrease in waste generation. According to Hoang [8], waste generation is affected by external factors, such as seasonal variations. This supports the idea that there are certain influences on the amount of waste generated. According to work by Gallardo et al. [29], who generated a map of MSW generation and composition, generation could be influenced by factors such as seasonal variation and the economic activity of a population. According to Taghizadeh et al. [30], university holidays have a significant impact on the seasonal variance of waste generation.

From this research it was observed that the moving average of the generated waste is usually at its peak in March and May, and there was a decrease of approximately −8% in the total moving average waste generation between its peaks, from 1122 tons in April 2015 to 1031 tons in March 2016. This result confirms the downward trend over the period of study (October 2014 to October 2016), and aligns with the findings of Zhang et al., [31], who explored the trend of solid waste generated in five areas of a university campus, the Longzi Lake Campus of Henan Agricultural University, in Zhengzhou City, China and the factors that influence the potential for recycling of the waste. The authors showed a downward trend in the waste generation pattern, where the estimated mean waste generation per month from November 2018 to October 2019 was 221 tons (7.32 tons daily), falling from 280.80 tons per month (9.36 tons daily) in November 2018, to 250.48 tons per month (8.08 tons daily) in October 2019. However, a peak in waste generation of 308.40 tons per month (10.28 tons daily) was recorded in April 2019.

The downward trend in waste generation demonstrated by Zhang et al. [31] is attributed to China's central government approval of the "No-Waste City" Pilot Program in December 2018. This is a city development model that incorporates the ideas of innovation, greenness, coordination, and sharing, which aims to minimize the amount of solid waste that ends up in landfills and the negative environmental effects of solid waste. The current research findings and those of Zhang et al. [31] are commendable as progress towards more sustainable waste management.

Accurately forecasting waste generation capacity and trends remains crucial for strategic planning and cost-effective budgeting. Research conducted by Chalkias et al. [32] and O'Connor et al. [33] reveals that a sizeable portion, more than 60%, of waste management budgets is dedicated to waste collection and transportation. Thus, by understanding waste generation patterns, opportunities arise to optimize waste management strategies, potentially resulting in reduced waste generation and lower costs for waste collection and disposal. These benefits are achievable because of the valuable insights the understanding of waste generation patterns give, by identifying which month has potentially high volumes of waste generation and developing targeted strategies to proactively handle it, including promoting reusable products, waste segregation, etc. Furthermore, this will offer valuable information for strategic infrastructure planning and efficient resource allocation, even in critical scenarios such as disease outbreaks [28,34–36]. By comprehending waste capacity and forecasting waste generation trends, it becomes possible to plan effectively for the entire waste management process [24,28,37].

It is widely recognized that educational institutions have a significant role to play in implementing strategies to create a more environmentally sustainable world, but specifically on-campus. These strategies encompass various methods such as waste reduction, reuse,

and recycling initiatives, as supported by several studies, e.g., Ramachandra et al. [38], Sharma et al. [39], and Ezeah et al. [15]. One can observe the decline in waste generation at this case study site, highlighting the university's strong commitment to implementing their waste management policy, especially the reduction approach. As stated by Armijo de Vega et al. [40], waste management policy plays a crucial role in the reduction and recovery of economically valuable recyclable materials at a high grade.

Implementing simplified waste management campaigns during student inductions, primarily through email communication, can help minimize waste generation, for example, promoting reduced printing of hard copies of papers among staff and students. This has the potential to enhance the university's waste reduction efforts.

Additional measures could also be implemented to not only sustain the current reduction in annual waste generation, but enhance it, further contributing to the progress of environmental sustainability. By implementing water fountains throughout the UoL campus, there could be potential waste reduction, especially from plastic waste streams, where the use of plastic water containers can be significantly reduced [41], a waste stream that has been highlighted in the work of Mbama et al. [17] to be a particular issue for UoL. This is vital as research indicates waste generation contributes to approximately 5% of global greenhouse gas (GHG) emissions; hence, this considerable proportion highlights the need for careful consideration of its negative impact. Therefore, reducing waste remains crucial in also indirectly mitigating GHGs [42,43].

To improve waste reduction and recycling efforts, it is essential to educate people about the advantages and proper use of colored bins for waste segregation [44]. Having a deep understanding of the waste trend can lead to significant cost savings in general waste management, by enabling the waste management team to gain insight on potential waste generation capacity and identify opportunities for cost savings like in optimizing resource allocation, including setting out required truck personnel and even scheduling predictive maintenance of equipment within the period with high waste volume, thereby preventing the breakdown of equipment and reducing unnecessary costs [45–47]. This thereby would result in additional economic and environmental savings for the institution. It can also help to develop more policies and the introduction of waste reduction initiatives towards meeting Sustainable Development Goal 12 [48,49].

Understanding the benefits of waste reduction, reuse, and recycling can increase the involvement of various individuals at the UoL, such as academics, staff, students, and visitors, which can be done by promoting awareness. Desa et al. [50] conducted a study on the impact of environmental awareness and education on solid waste management at the National University of Malaysia. They found that campaigns promoting environmental and waste awareness, along with effective communication strategies focused on environmental education, particularly waste reduction, reuse, and recycling, have shown positive results. These strategies have proven to be successful in promoting greater participation in sustainability, as demonstrated by Desa et al. [50]. In addition, the application of knowledge-based campaigns that target waste-related environmental and health concerns have the potential to encourage a positive change in attitudes towards safe waste management [51].

## 5. Conclusions

This study examined the waste generation patterns of the University of Lagos, a tertiary education institution located in Lagos, Nigeria. The aim was to improve understanding of the capacity and pattern of waste creation, which is crucial for implementing effective (sustainable) waste management techniques in the case study area.

The results indicated a gradual decrease in the amount of waste generated inside UoL during the duration of the study. The benefits of waste reduction are significant, and the advantages gained from this process provide a tangible strategy that can improve environmental sustainability. Hence, it is crucial to continue evaluating diverse waste management approaches that may further reduce waste generation. This entails promoting knowledge and understanding of the benefits of waste reduction, such as reusing and recycling, to

increase the involvement of various individuals (including academic and non-academic staff, as well as students) within university environments, hence improving sustainability.

## 6. Recommendations

1. It is recommended that waste management historical data is always analyzed to understand the trend/pattern to enable proactive and strategic waste management planning;
2. Higher resource allocation should be employed between the months of March and May as this period witnesses higher waste volume compared to other months;
3. It is also necessary to maintain or put strategic efforts towards sustaining the reduction in waste generation in the case study area.

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