# Quantification and Characterization of Solid Waste for Optimal Management: A Case Study of Lead City University, Ibadan

Idowu Ezekiel OLORUNFEMI[1], Solomon Ayobami ADEFISOYE[2], Abidat Olayemi FASASI-ALESHINLOYE[3], Ademola Mohammed ADEYEMI[4], & Abdulrasak Olamilekan AFOLABI[5]

+234-7037986945[1], +234-8069639574[2], +234-8039567943[3], +234-8033312398[4], +234-8067759667[5]

olorunfemi.idowu@lcu.edu.ng[1], adefisoye.solomon@lcu.edu.ng[2], fasasi.aleshinloye@lcu.edu.ng[3], adeyemi.ademola@lcu.edu.ng[4], afosstyleconstruction@gmail.com[5]

Department of Civil Engineering, Lead City University, Ibadan, Nigeria[1,2,3,5], & Department of Urban and Regional Planning, Lead City University, Ibadan, Nigeria[4]

## Abstract

This study analyzed and characterized solid waste generated at Lead City University (LCU) in Ibadan, with the purpose of evaluating waste disposal methods and identifying appropriate strategies for achieving sustainable solid waste recycling and management. The sampling locations for the two-month study period were chosen using a purposeful sampling technique. Data were collected at the following locations: Boys Hostel, University Mosque, Cafeteria, Faculty of Engineering, and College of Medicine. Plastics (35.21%) and Organic Waste (23.05%) accounted for the majority of the solid waste generated. Polyethene bags, food packs, other wastes, paper, metals, fabric, and e-waste represented 11.59%, 10.11%, 5.41%, 5.17%, 4.25%, 3.28% and 2.03%. Also, recyclable, non-recyclable, and compostable wastes cover over 62, 14, and 24%, respectively of the total waste generated at LCU during the 2-month sampling period. The total amount and percentage of non-biodegradable materials (95 kg and 73%) was substantially higher than that of biodegradable materials (35.3 kg and 27%). This characterization provides important information about the types and amounts of waste items produced on the university campus. The findings of this study provide valuable insights for improving solid waste management practices at Lead City University and other similar institutions. Recommendations include implementing thorough waste segregation programs, investing in recycling and composting facilities, and developing a sustainable waste management strategy customized to the university's specific needs. Addressing these issues is critical for establishing a cleaner and healthier environment on university campuses and contributing to larger sustainability goals.

**Keywords**: Solid waste, Waste characterization, Recycling, Environmental management, Lead
**Word Count**: 241

1. **Introduction**

Solid waste constitutes unwanted substances produced as a byproduct of human endeavors within our local jurisdiction. These are solid materials that have been deemed unnecessary and possess the potential to pose significant risks to human health if not appropriately managed (Mohammed et al., 2021). Solid waste refers to all the garbage and waste materials that are not in a liquid or gas form namely discarded paper, plastic, food waste, and other materials (Ojowuro et al., 2018). It is important to manage solid waste properly to protect the environment. Municipal solid waste (MSW) generation is an issue of worldwide concern (Onyelowe, 2018).

Globally, there has been an increase in the generation of solid waste from municipalities due to population growth, cultural changes, and people's attitudes regarding waste generation (Abdulredha et al., 2017). As per the findings delineated in the World Bank's report, What a Waste 2.0, it is anticipated that global waste generation will escalate by 70%, resulting in a substantial annual waste output amounting to approximately 3.40 billion metric tons of waste produced each year (World Bank, 2018; Maalouf & Agamuthu, 2023). In developing countries, majority of the municipal waste comes from households (55-80%), followed by commercial or marketplaces (10-30%), with different amounts coming from streets, industries, institutions, and other sources (Abdel-Shafy & Mansour, 2018). These wastes from diverse sources vary widely in their composition and physical characteristics, with different components such as plastics, metals, leathers, food waste, non-reactive materials, wood, fabrics and textiles, building and demolition materials, and many others (Miezah et al., 2015). The diverse composition of the municipal solid wastes limits straightforward classification and consequently pose a serious hold back in its application as a raw material (Abdel-Shafy & Mansour, 2018). As a result, waste must be separated before it can be efficiently treated and used for a variety of other purposes and activities.

The characterization of waste constitutes a fundamental component of any comprehensive waste management framework (Bassey et al., 2024). It is essential in facilitating treatment processes, enhancing operational efficacy, informing policy formulation, and supplying the necessary data for the advancement of pertinent community and national initiatives aimed at addressing waste management challenges (Afroz et al., 2010; Safo-Adu & Owusu-Adzorah, 2022). In order to develop appropriate strategies for the utilization of solid waste, it is essential to gather data regarding the volume, generation rate, and types of waste produced. Consequently, this research endeavor is designed to characterize the solid waste within the Lead City University Municipality, with the objective of establishing effective waste utilization strategies. The significance of dependable data concerning both the quantity and composition of municipal solid waste for the efficient planning of waste management emphasizes the pivotal role this study is poised to fulfill.

## 2. Statement of the Problem

Ineffective solid waste management practices pose a significant risk to public health and the environment due to their potential to cause pollution in air, soil, and water. The formulation of sustainable waste management strategies can commence through a comprehensive understanding of waste generation and its composition. The accessibility of data regarding waste generation and composition serves as the foundational element for the implementation of suitable waste management methodologies and technologies (Ugwu et al., 2020).

Numerous studies have systematically assessed the generation and composition of waste (Olukanni and Ugwu, 2013; Miezah et al., 2015; Adeniran et al., 2017; Abdel-Shafy & Mansour, 2018; Ojowuro et al., 2018; Ugwu et al., 2020; Safo-Adu & Owusu-Adzorah, 2022). Nevertheless, the formulation of an efficient waste management system necessitates comprehensive data and information pertaining to the precise quantities and classifications of solid waste produced within a specific localized context as the composition, quantities, and generation rates of solid waste differs in different locations (Adeniran et al. 2017). Based on this premise, it is reasonable to conclude that the success of solid waste recycling at establishments is determined by the waste's characteristics, volumes, and rate of generation. Even though Adeniran et al. (2017) and Ugwu et al. (2020) have carried out comprehensive waste characterization and quantification at two public universities in Nigeria: The University of Lagos (UNILAG) and the University of Nigeria, Nsukka (UNN). There is little or no information on solid waste quantification and characterization in the private universities. This study thus systematically quantified and characterized solid waste generated within the Lead City University campus, supplying essential data to formulate enhanced strategies for the treatment and management of solid wastes at LCU, thereby promoting sustainable management practices.

## 3. Methodology

The study was carried out in Lead City University, a private university located in Ibadan, the capital city of Oyo State, Nigeria. Established in 2005, LCU has grown in student population and infrastructure, as well as increased the rate of solid waste generation and thus not exempted from the challenges of solid waste management thereby making it an ideal case study for solid waste management within an educational institution. The study focused on several key locations of the university campus, including academic buildings, student hostels, administrative blocks, cafeterias, recreational areas, and other facilities that generate waste.

A purposeful sampling technique was employed to select Five (5) different locations of waste generation within the school, namely, the Boys Hostel, University Mosque, Cafeteria, Faculty of Engineering, and College of Medicine for the study. These areas were chosen due to their diverse demography and existing solid waste management challenges. The sampling was carried using the ASTM D5231-92 method (Standard Test Method for Determining the Composition of Unprocessed Municipal Solid Waste). In line with the standard procedure, waste samples were collected over a period of 8 weeks (2 months). The sample size (n) required was statistically determined using equation provided in the ASTM D5231-92 method:

$$n = \left(\frac{T \times S}{E \times X}\right)^2 \qquad (1)$$

where T is the student's t-test corresponding to the desired confidence level, S is estimated standard deviation, E is the desired precision level, and X is the estimated mean. The statistical criteria employed in the determination of the exact samples include a T value of 1.645 (90% confidence level) with a desired precision of 10 % (i.e. E = 0.1). Using Plastic as the governing waste composition, the values of S and X were determined from the ASTM D5231-92 as 0.03 and 0.09, respectively. Therefore, the value of n was determined to be 30 from Eqn. (1).

Sampling was carried out from March 2024 to May 2024 at the respective locations. Plastic bags were provided for the collection of the wastes at each location. All waste was collected at the generation site, labeled, and then transported to a sorting facility for segregation and weighing. The waste was collected and segregated according to its components. The total solid waste collected were manually sorted to determine the values of each component and the wastes were sorted into nine (9) categories namely polythene bags, paper, plastic, food/organic wastes, metals, food packs, fabrics, ewaste and other wastes. Each sorted composition's weight was determined and noted using a weighing balance and the amount of solid waste ranged between 3 and 52 kg. The weights of the constituent components were combined to determine the total amount of waste generated at a specific collection site on a daily basis. The average daily weight of all collected wastes was 123.75 kg, which falls within the required sorting weight range (200-300 lb (91-136 kg)) for each unprocessed solid waste sample.

Differentiating the solid wastes among recyclable and non-recyclable categories was done after obtaining the weight percentage of each individual component. The study also estimated the differences between biodegradable and non-biodegradable wastes, along with the percentage composition of each type.

## 4. **Results**

Tables 1 shows the average quantity of waste per day and the total quantity of waste generated during the 2-month sampling period. The results in Table 1 demonstrated significant variation in the composition of solid waste generated in the LCU. Boys Hostel had the highest average total quantity 51.27 (± 5.49) kg of solid waste produced, followed by Marigold 37.26 (± 4.88) kg, College of Medicine 18.03 (± 1.75) kg, Faculty of Engineering 14.22 (± 2.78) kg and University Mosque 2.98 (± 0.24) kg. In terms of the overall waste categories generated in all the sampled locations, Plastics (35.07%) and Organic Waste (22.96%) accounted for the majority of the solid waste generated. Polyethene bags, food packs, other wastes, paper, metals, fabric, and e-waste represented 11.59%, 10.11%, 5.65%, 5.15%, 4.24%, 3.27% and 2.03%.

Plastic waste accounts for approximately 35% of the total waste produced, making it the largest recyclable category of MSW on campus. Notably, the boys' hostel generates the highest amount of plastic waste, producing, on average, over 21 kg of paper waste daily. The Marigold building is the largest contributor of organic waste, producing over 24 kg of organic waste daily. On average, the boys Hostel recorded the highest composition of plastics (48.91%), polyethene bags (52.70%), food packs (69.42%), fabrics (87.18%), e-waste (74.41%) and other wastes (34.81%). Marigold recorded the highest composition of paper (37.76%), food/organic wastes (84.52%), and metals (64.04%). The faculty of Engineering recorded the least fabric (1.40%) and organic wastes (1.07%) while the lowest levels of polythene, paper, plastic, metals, food packs, e -waste and other wastes were obtained at the University Mosque.

Table 1 Average Solid waste generated per day (kg)

| Categories/Collection Sites | Boys Hostel | College of Medicine | University Mosque | Marigold | Faculty of Engineering | Total (kg) | Total (%) |
|---|---|---|---|---|---|---|---|
| Polyethene | 7.66 | 2.40 | 0.33 | 2.15 | 2.00 | 14.54 | 11.55 |
| Paper | 2.06 | 0.98 | 0.41 | 2.45 | 0.58 | 6.48 | 5.15 |
| Plastic | 21.58 | 9.48 | 1.73 | 3.67 | 7.65 | 44.12 | 35.07 |
| Organic | 1.68 | 0.76 | 1.73 | 24.42 | 0.31 | 28.89 | 22.96 |
| Metal | 1.55 | 0.15 | 0.03 | 3.42 | 0.20 | 5.33 | 4.24 |
| Food packs | 8.80 | 2.24 | 0.23 | 0.47 | 0.95 | 12.67 | 10.07 |
| E-waste | 1.90 | 0.15 | 0.00 | 0.01 | 0.50 | 2.55 | 2.03 |
| Fabric | 3.59 | 0.36 | 0.08 | 0.03 | 0.06 | 4.12 | 3.27 |
| Other waste | 2.48 | 1.84 | 0.17 | 0.65 | 1.98 | 7.11 | 5.65 |
| Total (kg) | 51.27 | 18.36 | 4.70 | 37.25 | 14.22 | 125.79 | |
| Total (%) | 40.76 | 14.59 | 3.74 | 29.61 | 11.30 | | |

Figure 1 shows the average amount of recyclable and non-recyclable wastes generated in LCU. Averagely, 90% of the solid waste generated in LCU are potentially recyclable while 10% of the wastes are not recyclable. The distribution of recyclable waste was in the order of Boys Hostel > Marigold > College of Medicine > Faculty of Engineering > University Mosque while the distribution of non-recyclable waste was in the order of Boys Hostel > College of Medicine > Faculty of Engineering > Marigold > University Mosque. The indicate a substantial variation in the quantity of recyclable and nonrecyclable wastes in the university.

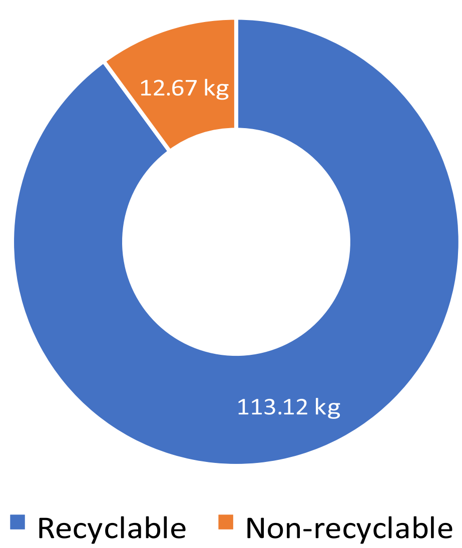


Figure 1 Average amount of recyclable and non-recyclable wastes (kg)

These are two different types of waste based on their potential to degrade naturally as illustrated in Figures 2 and 3. Figure 2 shows the percentage levels of biodegradable and non-biodegradable wastes generated at each collection sites within the school. Marigold has the largest percentage of biodegradable wastes (72.12%) in its solid waste stream followed by the University Mosque (45.56%), whereas Boys hostel, College of Medicine, and Faculty of Engineering had the highest percentage levels of non-biodegradable waste in their solid waste collection. Faculty of Engineering has the highest percentage of non-biodegradable waste in its solid waste stream (93.72%), followed by Boys Hostel (92.72%), College of Medicine (90.54%), University Mosque (54.44%) and Marigold (27.88%). On average, the biodegradable composition of the solid waste generated in all the collection sites accounted for just 28.11% of the total waste generated while 71.89% of the solid waste are non-biodegradable (Figure 3). The total daily quantity of non-biodegradable materials (90.43 kg) recorded in all the collection sites is substantially higher than that of biodegradable materials (35.36 kg) (Figure 3). This suggests that a larger portion of the daily waste generated within the LCU campus is non-biodegradable.

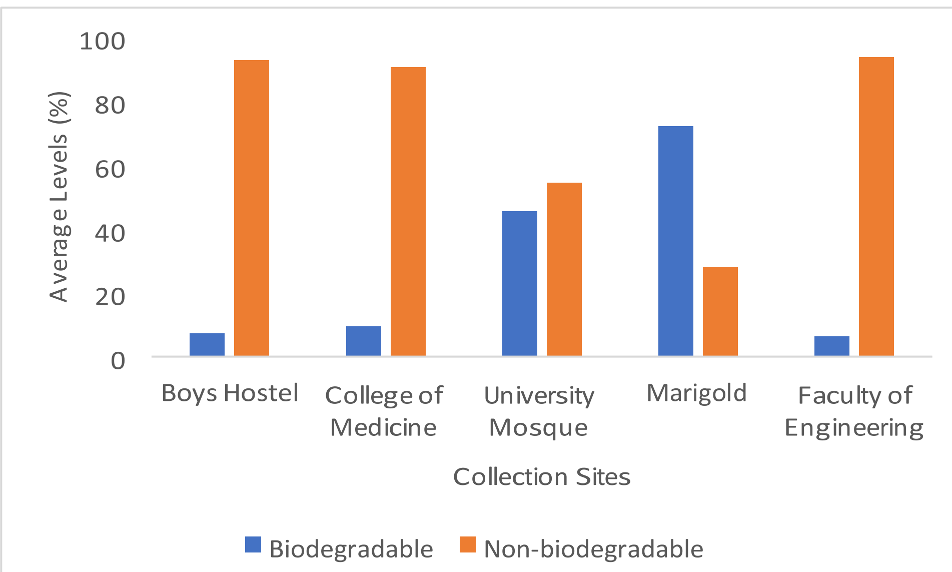


Figure 2 Levels of biodegradable and non-biodegradable wastes generated in collection sites.

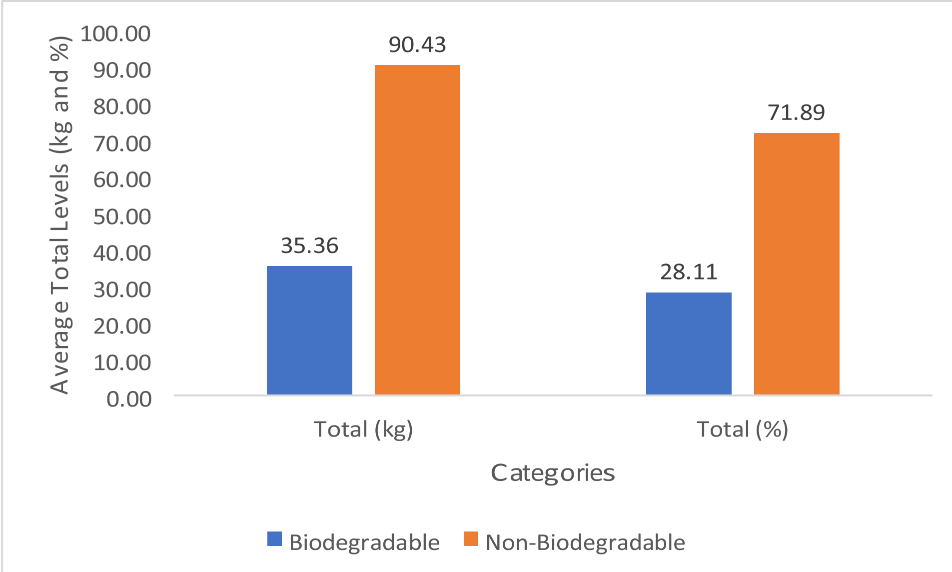


Figure 3 Levels of biodegradable and non-biodegradable wastes generated

5. **Discussion of Findings**

According to the results of the solid waste characterization, plastics made up the largest portion of the municipal solid waste produced at Lead City University, Ibadan.

The high proportion of plastics may be attributed to their low cost, adaptability, and sterility as well as their use in a variety of products, including food packaging, medical equipment, home appliances, construction, and automotive parts. Polyethylene terephthalate (PET), a major plastic that makes up a sizable amount of municipal solid waste (MSW), is frequently found in bottles for soft drinks, liquors, and water. Furthermore, broken kitchenware, buckets, plates, chairs, and cooking utensils frequently produce high-density plastics (Ugwu et al., 2020). The percentage of plastics identified in this study is lower than the 8.53% reported by Ugwu et al. (2020) from the

University of Nigeria, Nsukka (UNN), in their analysis of the overall waste stream. Also, plastics made up 9% of the total solid waste produced at the University of Lagos, Akoka (UNILAG) (Adeniran et al., 2017). Our study's comparatively higher plastics percentage compared to other Nigerian institutions may be related to the growing use of plastics in daily life; plastic production has increased dramatically from 1.5 million metric tonnes in 1950 to over 413 million in 2023, with projections showing a sharp rise by 2040. However, when plastic waste is mismanaged and not recycled becomes an environmental pollutant. In order to minimize the impact on the environment and the demand for new plastic production, recycling is essential. Food and organic trash account for the second largest proportion (22.96%) of total solid waste generated at campus collection sites. These nutrient-rich organic waste materials are highly biodegradable, meaning that microorganisms can readily break them down. Common examples include fruit and vegetable peels, coffee grounds, eggshells, grass clippings, and leaves (Nyumah et al., 2021). These types of solid waste can be used to create compost, which is a partially decomposed organic matter that improves soil structure, water retention, and fertility. As such, composting these products not only lowers waste sent to landfills, but it also creates a useful soil amendment that increases soil health, moisture retention, and plant development. Because of the huge volume of organic waste generated on campus, the University can implement composting programs or initiatives to generate compost and revenue from waste.

Another type of plastic, polythene bags, accounted for 11.55% of total solid waste created, ranking as the third-largest recyclable category of municipal solid waste (MSW) on campus. Together, plastic and polythene bags accounts for 46.63% of the total solid waste stream. Paper is another significant source of solid waste generated on campus; it makes up 5.15% of the total waste generated and is the third-largest recyclable category of solid waste. The widespread usage of paper, particularly in academic institutions, may explain the level of paper waste generated on campus. The 5.15% paper waste found in this study is lower compared to the 14.05% and 15% of total waste generated at UNN and UNILAG, as reported by Ugwu et al. (2020) and Adeniran et al. (2017). Lower paper use in this study compared to previous studies could be attributed to cost savings and increased acceptance of digital technologies such as cloud storage and electronic signatures.

The biodegradable and non-biodegradable components of solid wastes make up around 28 and 72%, respectively. The 28% biodegradable weight indicates that there are materials present that can decompose naturally. Wastes like these can be composted, and anaerobic digestion can also be utilized to generate methane from them. The advantages of these management strategies include a decrease in landfill waste and the simultaneous production of nutrient-dense compost. This will either directly or indirectly enhance agricultural output and food security, thus aiding the Sustainable Development Goal (SDG 2) of Zero Hunger, as the global challenges of malnutrition and food scarcity have significantly intensified since 2015 (United Nations Statistics Division, 2023). Though the high amounts of non-biodegradable waste can be concerning owing to their persistent influence on ecosystems and their propensity to infiltrate the food chain, the majority of these categories of waste can be recycled, such as plastic, metals, e-waste, etc. The 90% recyclable garbage highlights the excellent recycling potential of the solid waste produced on campus. Recycling minimizes landfill volume and energy use, while also conserving natural resources. By boosting recycling rates, we can contribute to establishing a circular economy that minimizes waste and its environmental effects through the ongoing reuse of materials

## 6. Conclusion

The study quantified and characterized solid waste generated at Lead City University. Plastic and food/organic waste accounted for the majority of total solid waste, with 35.07 and 22.96%, respectively. The waste characterization revealed that roughly 28 and 72% of the average total solid waste generated are biodegradable and non-biodegradable, respectively. Averagely, 90% of the solid waste generated in LCU are potentially recyclable while 10% of the wastes are not recyclable. The distribution of recyclable waste was in the order of Boys Hostel > Marigold > College of Medicine > Faculty of Engineering > University Mosque while the distribution of non-recyclable waste was in the order of Boys Hostel > College of Medicine > Faculty of Engineering > Marigold > University Mosque. The high proportion of plastics may be attributed to their low cost, adaptability, and sterility as well as their use in a variety of products, including food packaging, medical equipment, home appliances, construction, and automotive parts. Because of the huge volume of organic waste generated on campus, the University can implement composting programs or initiatives to generate compost and revenue from waste. The 90% recyclable garbage highlights the excellent recycling potential of the solid waste produced on campus.

## 7. Recommendations

The research suggests that increased public awareness, funding, skills; tools, and infrastructure alongside other necessary resources that are currently insufficient or unsuitable need to be supplied.

i. Organic waste can be composted to produce nutrient-rich soil amendments, which promote healthy plant development and reduce the need for chemical fertilisers.

ii. The university and towns should implement metal and plastic recycling initiatives to encourage proper metal disposal, recovery and recycling, so promoting a circular economy.

iii. Implement a mechanism for the regular monitoring and reporting of material and waste composition to assess progress towards sustainability objectives. iv. Subsequent research can perform longitudinal evaluations to produce historical data, enabling the comparison of these percentages over time to determine whether there is an upward or downward trend in the utilisation of biodegradable and recyclable materials.

**References**


Abdel-Shafy, H. I., & Mansour, M. S. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum,* 27(4), 1275–1290. https://doi.org/10.1016/j.ejpe.2018.07.003

Abdulredha, M., Khaddar, R. A., Jordan, D., & Hashim, K. (2017). The Development of a Waste Management System in Kerbala during Major Pilgrimage Events: Determination of Solid Waste Composition. Procedia Engineering, 196, 779–784. https://doi.org/10.1016/j.proeng.2017.08.007

Adeniran, A., Nubi, A., & Adelopo, A. (2017). Solid waste generation and characterization in the University of Lagos for a sustainable waste management. Waste Management, 67, 3–10. https://doi.org/10.1016/j.wasman.2017.05.002

Afroz, R., Hanaki, K., & Tudin, R. (2010). Factors affecting waste generation: a study in a waste management program in Dhaka City, *Bangladesh. Environmental Monitoring and Assessmen*t, 179(1–4), 509–519. https://doi.org/10.1007/s10661-010-1753-4

Bassey, U., Tom, A., Okono, U., John, M., Sinn, M., Bassey, A., Luke, U., & Narra, S. (2024). Characteristics and management of municipal solid waste in Uyo, Akwa Ibom state, Nigeria. Scientific Reports, 14(1), 10971. https://doi.org/10.1038/s41598-024-61108-0

Maalouf, A., & Agamuthu, P. (2023). Waste management evolution in the last five decades in developing countries – A review. Waste Management & Research, *the Journal for a Sustainable Circular Economy,* 41(9), 1420–1434. https://doi.org/10.1177/0734242x231160099

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B., & Mensah, M. Y. (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. Waste Management, 46, 15–27. https://doi.org/10.1016/j.wasman.2015.09.009

Mohammed, T. J., ALMukhtar, R., Elias, N. M., Fakhri, L., Sameer, A., & Dawoud, E. A. (2021). Solid waste characterization at University of Technology-Iraq - step for sustainable development. IOP Conference Series Earth and Environmental Science, 779(1), 012072. https://doi.org/10.1088/1755-1315/779/1/012072

Nyumah, F., Charles, J. F., Bamgboye, I. A., Aremu, A. K., & Eisah, J. S. (2021). Generation, characterization and management practices of household solid wastes in Cowfield, Paynesville City, Liberia. *Journal of Geoscience and Environment Protection*, 09(04), 113–127. https://doi.org/10.4236/gep.2021.94007

Ojowuro, O. M., Olowe, B., & Aremu, A. S. (2018). Characterization of Municipal Solid Wastes from Lagos Metropolis, Nigeria. In Springer eBooks(pp. 159–166). https://doi.org/10.1007/978-981-10-7290-1_13

Olukanni, D.O., Ugwu, N.C. (2013). Analysis of municipal solid waste management in Ota, Ogun State, Nigeria: potential for wealth generation. *Int'l J. Water Res. Environ. Eng. IJWREE* 5, 262–271

Onyelowe, K. C. (2018). Review on the role of solid waste materials in soft soils reengineering. *Materials Science for Energy Technologies*, 2(1), 46–51. https://doi.org/10.1016/j.mset.2018.10.004

Safo-Adu, G., & Owusu-Adzorah, N. (2022). Solid waste characterisation and recycling potential: A study in secondary schools in Kumasi Metropolis, Ghana. Cleaner WasteSystems, 4, 100065. https://doi.org/10.1016/j.clwas.2022.100065

Ugwu, C. O., Ozoegwu, C. G., & Ozor, P. A. (2020). Solid waste quantification and characterization in university of Nigeria, Nsukka campus, and recommendations for sustainable management. *Heliyon*, 6(6), e04255. https://doi.org/10.1016/j.heliyon.2020.e04255

United Nations Statistics Division (2023). The Sustainable Development Goals Report 2023:SpecialEdition.SDGindicators. https://unstats.un.org/sdgs/report/2023/

World Bank (2018). Trends in Solid Waste Management. Available at: https://datatopics.worldbank.org/what-awaste/trends_in_solid_waste_management.html