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Sustainable Eco-friendly Campus-centric Plastic Waste Management – A case Study of University of Delta Agbor (UNIDEL), Nigeria

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ABSTRACT

This paper discusses an ongoing project at the University of Delta, Agbor, where a bailing machine has been integrated into the campus waste management system, alongside the fabrication of a plastic crushing machine. The Plastic Wastes (PW) is found all in corners of the environment, the park, the canteen, the laboratory, the hostel and the university surrounding at large. The average plastic waste generated on daily basis from University of Delta, Agbor is over 550g with Polytethylene Terapthalate constituting the largest proportion of about 80% hence the need of this initiative. Smart bins were fabricated and placed in the respective faculties and campuses which are 100m apart from each other while the University cleaners were incentivized to optimize waste collection efficiency. The study has embraced circular economy principles, engage students in hand-on learning relative to environmental stewardship, help UNIDEL reduce plastic waste menace, and ensure entrepreneurial value creation on campus and the host communities. The study collaborated with relevant stakeholders within and outside the University, frequent workshops and seminars for behavioral change that will ensure proper waste disposal and facilitated recycling process as well as other plastic transformation processes to increase recycling efficiency of Plastic waste for UNIDEL.

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1. INTRODUCTION

Plastic pollution remains a global crisis, with less than 10% of plastic waste being effectively recycled. University campuses produce large volumes of single-use plastics, offering a controlled environment to test innovative recycling strategies. This plastic recycling project at University of Delta supports the Intergovernmental Panel on Climate Change (IPCC) which exemplifies the IPCC's comprehensive management principles of reduce, reuse, and recycle. By integrating these principles into its framework, the project not only aims to address the immediate challenges of plastic waste management on campus but also contributes to broader efforts in mitigating greenhouse gas emissions and promoting sustainability in alignment of the IPCC policies, this project primarily aims to reduce the generation of plastic waste on campus by implementing effective recycling practices and promoting awareness among students and staff through educational campaigns and improved waste management strategies, the initiative encourages the campus community to minimize single-use plastics and make more sustainable choices, thereby reducing the overall volume of waste produced (IPCC, 2022). The project also seeks to foster a culture of reuse within the university environment by encouraging the use of refillable containers and repurposing materials whenever possible. And finally, enhancing the recycling capacity on campus through the fabrication of a bailing and crushing machine to facilitate the recycling of plastic waste. A recycling project at a university is not only a practical solution to managing plastic waste but also a vital component of the institution's broader mission to educate and lead in sustainability efforts. By undertaking this initiative, universities can create a more sustainable campus environment, enrich the educational experience, engage the community, and contribute positively to the global challenge of plastic pollution and climate change. This project reflects a proactive approach to research as one of the core pillars that resonates with the values and responsibilities of higher education institutions.

As of the 2024/2025 academic session, the University of Delta (UNIDEL), Agbor, has an estimated population of approximately 10,500 individuals, which includes 9,000 undergraduate 1,000 academic and non-academic staff, 500 external daily visitors, including vendors, parents, and service providers. Prior to this intervention, plastic waste at UNIDEL was managed through informal and unstructured systems with waste not separated at source, plastics mixed with other waste streams in general disposal bins, waste collected by municipal or contracted waste collectors and disposed of in open dumps, no on-campus recycling, recovery, or formal awareness campaigns existed. Some students informally collected PET bottles for local recyclers, but this was uncoordinated and small-scale. To assess the plastic consumption habits of the UNIDEL population, a structured questionnaire was distributed across different demographics within the campus (students, staff, vendors). The preliminary findings showed that Over 90% of respondents consume plastic-packaged water (PET bottles or sachet water) daily. About 70% use takeaway food packs or plastic wraps at least 3 times per week. Less than 15% separate their plastic waste from other waste. And over 80% expressed willingness to participate in plastic recycling if infrastructure was provided.

Previous studies have identified multiple barriers in traditional recycling systems: logistical inefficiencies, quality degradation,

and consumer apathy. Emerging technologies such as distributed recycling and additive manufacturing offer potential solutions. Projects like Wecyclers in Lagos Island and Recycle Points in Ebute Metta Lagos have inspired small-scale approaches, but their academic integration remains limited. For instance, the We cyclers is a social enterprise that provides an affordable and convenient way for households in Lagos to recycle their waste using fleet of bicycles to collect recyclable materials directly from homes. They have successfully created a community-based recycling program that not only diverts waste from landfills but also empowers residents by providing them with rewards for their participation but with no educational relevance (Kazeem, 2022). The Recycle Points operates a rewards-based recycling program. They encourage individuals and businesses to recycle by providing incentives such as rewards points that can be redeemed for cash or goods purposes only. The Nigerian Breweries Plc (NB Plc), as one of Nigeria's largest breweries, has also recognized the importance of sustainability and has initiated several recycling programs as part of its corporate social responsibility (CSR) efforts banking on only owed plastics. Hence, the initiative to create a closed loop system on campus solution unlike conventional approaches reliant on external recycling facilities. The choice to fabricate key equipment locally specifically, the bailing and crushing machines reflects a commitment to sustainable design, hands-on learning, and a reduction in the carbon footprint associated with transportation. Recycling fosters sustainable material management, minimizing waste generation through prevention, reduction, reuse, and recycling (UN, 2015). Recycling reduces emissions from waste incineration and landfills and lowers industrial energy needs, helping combat climate change (UNEP, 2021) aligning with SDG 13. Recycling programs promote cleaner urban environments and reduce the burden on municipal waste management systems. This contributes to making cities more resilient and sustainable (World Bank, 2020) aligning with SDG 11. Proper recycling helps prevent pollution of water bodies from plastic and other waste materials, thus supporting water quality and sanitation efforts (WWF, 2022).

This paper describes the design, deployment, and preliminary outcomes of a decentralized micro-factory system developed to close the plastic loop entirely within campus and the community boundaries of the University of Delta, Agbor. The impetus for this project stems from several factors which include High Plastic Waste Generation, for example in the campus like many academic institutions, generates substantial plastic waste from various sources (e.g., food packaging, disposable containers, lab supplies). Another is Limited Recycling Infrastructure, some existing recycling systems often lack the capacity to handle the volume and types of plastic waste efficiently in the South-South region of Nigeria. The project provides invaluable opportunities for students to engage with environmental issues in a practical, problem-solving setting, supporting the university's mission of fostering environmental stewardship. Lastly, fabricating the machines locally allows for cost-effective solutions, as well as customization based on the specific plastic waste streams generated on campus.

The design and operational strategies for the bailing and crushing machines are informed by existing literature in waste management and mechanical engineering. Relevant sources include:

i. Research on the design and efficiency of bailing machines (e.g., studies on the impact of bale density on transportation efficiency).

ii. Studies on plastic crushing technologies, including different crushing blade designs and their effectiveness on various plastic polymers (e.g., PET, HDPE).

iii. Best practices for campus sustainability initiatives (e.g., successful models from other universities).

iv. Engineering guidelines for the design and fabrication of machinery, including safety protocols and material selection.

2. METHODOLOGY

2.1 Site and Scope

The collections of plastics waste were done in the University of Delta, Agbor Delta State, Nigeria. Agbor is situated on latitude 6° 15' 50.7312" N and longitude 6° 12' 6.7788" E. The campuses involved are the Main campus, Alihame, Owa-Alero, campus, Owa-Oyibu, campus and old site, college, Alihame. The main campus is situated at Agbor metropolis in Ika South Local Government Area, while, Owa-Alero and Owa-Oyibu in Ika North East Local Government Area respectively. The project site for accumulation and preparedness of plastic wastes to be subjected for recycling purpose was Owa-Alero, campus.

Using the ASTM D5231-92 standard test method for determining the composition of unprocessed municipal solid waste, plastic waste characterization was carried out to quantify and analyze the types and volumes of plastic waste generated. Results indicated that the university generates approximately 20–25 kg of plastic waste daily, amounting to over 800 kg so far, primarily consisting of PET bottles, food wrappers, soda cans and sachet water films. The map of University of Delta in Agbor and its host communities is shown in Figure 1.

The development of the site started with clearing and leveling as shown in Figure 2a and Figure 2b.

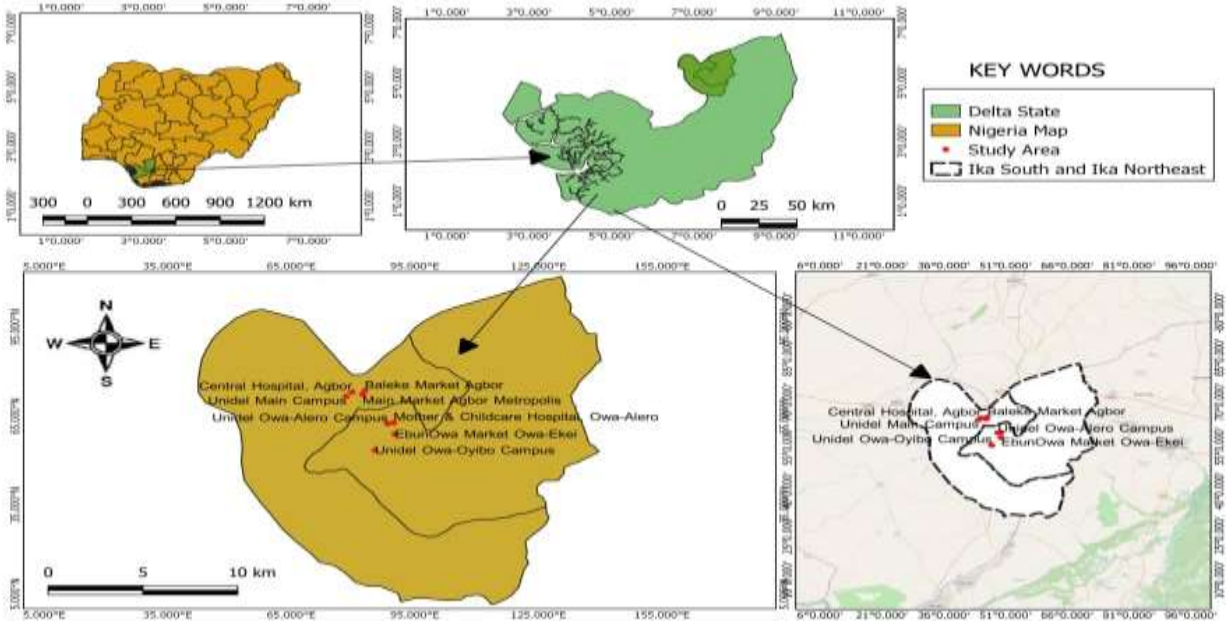


Figure 1: Map of the University location in Agbor



Figure 2a: Developing of site



Figure 2b: Fencing

2.2 Machine Design and Fabrication

2.2.1 Bailing Machine

Design of the Bailing Machine: The bailing machine was designed with a focus on compactness, operational simplicity, and ability to handle diverse plastic types. Design specifications included bale size, compaction force, and material handling (e.g., feed hopper and discharge system). CAD software was used to develop the initial designs (Geyer, Jambeck, & Law, 2017). Table 1, shows the general specification while Table 2, shows the machine parts and materials description of the bailing machine.

Table 1: Bailing machine general specification

Parameter	**Specification**
Type	Vertical Manual/Hydraulic Bailer
Bale size(L*W*H)	600mm*400mm*500mm
Bale weight	100kg-150kg
Compression force	10-30 tonnes
Cycle time	4-5minutes
Production capacity	2-3 bales/hour

Table 2. Machine Parts and Materials

Component	**Material**	**Description**
Frame structure	Mild steel (50*50*) mm	Welded frame heavy-duty for structural support
Compression plate	Mild plate (10-12 mm thick)	Rigid plate attached to ram
Chamber walls	Mild steel sheet (5-8 mm thick)	Inner baling area-flats bars
Hydraulic cyclinder	Double acting 100-150 mm	For compressing material
Hydraulic pump	3-5 HP electric motor-gear	Used in hydraulic models; manual jack
Oil tank	Mild steel 80litres	Stores hydraulic fluid
Ram	Mild steel square bar	Transfers pressure from hydraulic cylinder to bale

Control valves	Standard hydraulic valve system	Controls direction and pressure of hydraulic fliud

Fabrication of the Bailing Machine: The machine was fabricated in the campus's engineering workshop using locally available materials. The process involved cutting, welding, and assembling various metal components based on the design specifications. Some engineering students were actively involved in the fabrication process, gaining practical experience on machine building. The bailing machine is shown in Figure 3a and Figure 3b.



Figure 3a: Fabrication of the bailing machine



Figure 3b: Fabrication of the bailing machine

Testing and Optimization of the Bailing Machine: The machine was subjected to rigorous testing to ensure it meets the required performance standard, which is efficiency, bale density, and safety standards. Some adjustments were made from time to time during operation to optimize the operational parameters. The test operation is as seen in Figure 4.



Figure 4: Test running of the machine

2.2.2 Crushing Machine

Design of the Crushing Machine: The crushing machine design focused on processing the plastic waste into uniform-sized flakes. The design considerations involved the type of cutting mechanism that is the blade configuration, motor power, throughput capacity, and safety features. Design was aided using simulation software to refine the blade profile and crushing chamber dimensions (Li, Zhang, & Xu, 2020). Table 3 and 4 shows the general specification and components parts of the machine

Table 3. Crushing machine general specification

Parameter	**Specification**
Type	Blade crusher
Crushing capacity	200-300kg/hour
Input/ output size	70mm/10mm
Power source	Electric motor
Cycle time	4-5minutes
Discharge system	Gravity outlet

Table 4. Crushing Machine Parts and Materials

Component	**Material**	**Description**
Cushing chamber	Mild steel (7mm)	Contains rotating parts
Rotating shaft	Medium carbon steel	Drives blades
Blades	Hardened tool steel	Cuts and pulverizes
Motor mount	Mild steel plate	
Pulley and belt drive	Cast iron	Transfers power from motor to shaft
Bearings	Pillow block bearings	Shaft support and smooth rotation
Hopper	Mild steel sheet 3mm	Guides the material into the crushing chamber
Frame base	Mild steel	Directs crushed material out

Fabrication of the Crushing Machine: Similar to the bailing machine, the crushing machine was fabricated in the campus engineering workshop. The manufacturing process used a variety of techniques from cutting tools to machining tools. Material considered were of

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high durability, good wear resistance (to withstand abrasive plastics), and recyclability machine components. A comprehensive safety protocol was established and followed at all fabrication stages. Safety features incorporated into the design, such as safety interlocks, emergency stops, and protective barriers, were installed to prevent accidents and ensure compliance with safety regulations.

2.3 System Design

The micro-factory consists of:

2.3.1 Collection Units: Smart bins are placed in all corners of the campus for easy dispose of the plastics by staff and students. Some of the collection points is as seen in Figures 5a-5d. Also in the collecting plastics from the various campuses a mini vehicle was purchased to collect and move the plastics to the recycling field. Amongst the various types of plastics used for the research study were polymers comprising of Polypropylene



Figure 5a: Collection point at one of the campuses



Figure 5b: A plastic collection point at one of the campuses



Figure 5c: The mini vehicle for collection



Figure 5d: A drum collection bin sited at the Alihame campus

(PP), Polyvinyl Chloride (PVC), Polyetheylneterapthalate (PET), Polysterene (PS), Low Density Poly Ethylene and High Density Poly Ethylene (HDPE).

2.3.2 Sorting and Washing: The sorting of the plastics was done according to color and nature of the plastic as seen in Figure 6, where some students are participating in the process.



Figure 6: Some of the plastics being sorted by some students on site



Figure 7: One of the Clean-up drive in one of the campuses with student volunteers

2.4 Engagement Design

The initiative partnered with environmental clubs, fine art students, and other faculties to carry out a clean-up drive as part of the

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awareness campaign. This was done in and out of campus to set precedent. Figure 7 displays one of the in-house campaigns.

3. RESULTS AND DISCUSSION

3.1 Volume of Plastic Processed

The operational workflow involves collecting plastic waste from designated bins, sorting by type, bailing and crushing for other applications. In the first 6 months, over 3000 kg of plastic was collected and 2500 kg preprocessed in the month of May and June of 2025. Figure 8 shows that there was a significant increase in the volume of plastic collected and sorted from month to month in the first six months of this initiative, with a 30% increase in bailing productivity since the machine's implementation.

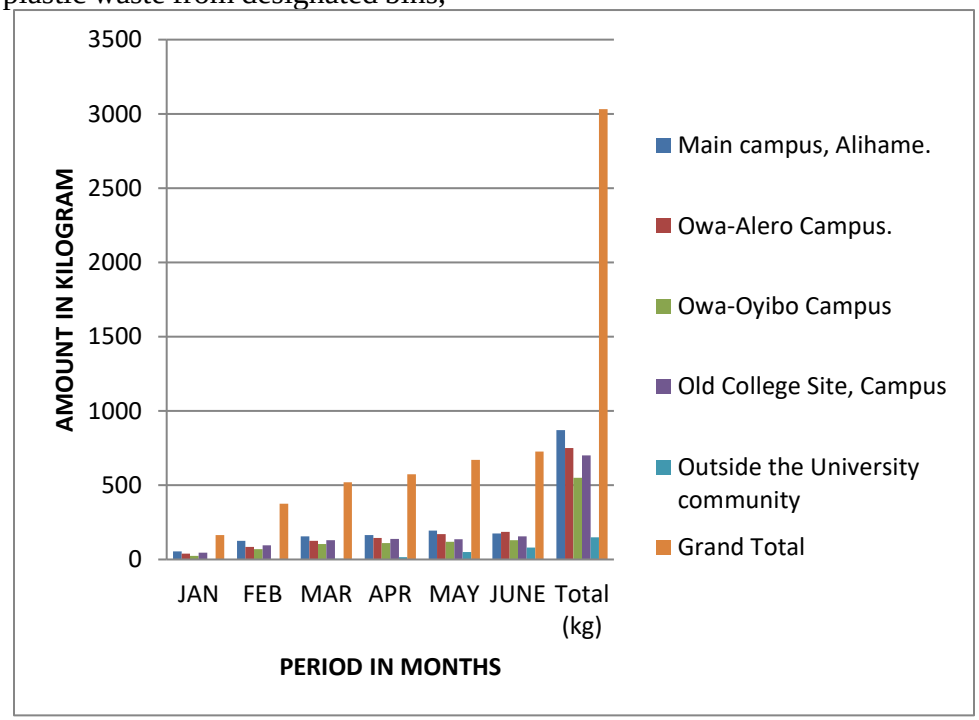


Figure 8: Chart display of the amount of plastic sorted from January-June 2025 (*1 ton=1000kg*)



Figure 9. The first set of bailed plastics in display

3.2 Output Quality (Bailing Operations)

Figure 9 shows a set of bailed plastic after the first run.

3.3 Environmental and Educational Impact

Preliminary lifecycle analysis suggests a 65% reduction in plastic littering the campus environment. The University of Delta is aiming to lead in the global plastic waste management with practical measures, awareness campaigns and the support of the local communities. The project has fostered interdisciplinary collaboration among students from environmental science, engineering, and art disciplines. Students are actively involved in the technical aspects of machine operation and maintenance, some in the awareness campaigns promoting recycling in campus and visually. Over 250 students so far participated through workshops, awareness campaigns using their self-made content posting a various social media platform and doing daily cleanup exercise. Some of these contents can be viewed on the university platforms (UNIDEL or University of Delta Agbor on facebook, #FEFPlasticProject #PlasticFreeCampus)

Future Work

The project considers acquiring an extrusion machine or an injection molding machine to convert recycled plastics in 3D filament, the use of sensors for automated operations. Chemical pyrolysis, Microfiltration and other biodegrable alternatives is also under considerations. Measures are in place to ensure that Delta State government pay more attention to this environmental menace on campuses by providing these facilities in all campuses of the state and perhaps within the reach of every local government.

4. CONCLUSION

The current generation rate, while seemingly moderate, poses significant environmental and logistical challenges due to the lack of structured segregation and processing systems. Currently, plastic waste is largely unmanaged, indiscriminately dumped or burned, resulting in pollution, aesthetic degradation, and potential health hazards. These findings underscore the inadequacy of the current plastic waste management strategy within the campus and the urgent need for aeco-friendlier, circular model.

The study examined the minimization potential of plastic waste through behavioral change, source segregation, volume reduction (via bailing and crushing), and value addition through recycling partnerships. Implementation of a locally fabricated bailing machine designed with cost-effective and accessible materials was proposed as a central intervention to address the twin issues of plastic volume and recycling readiness. This intervention has reduced the bulk of waste by over 70%, ease storage and transportation, and significantly increase the market value of the recovered plastic materials within the locality. This works aligns with the UN Sustainable Development Goals (SDGs) on responsible consumption and production (SDG 12) and climate action (SDG 13).Though the fluctuation in waste generation rates and composition throughout the seasons were not considered, yet the data gathered is adequate.

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