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Categorization of Plastic Waste Generated for Conceptualization of Pyrolysis Plant Development in Agbor Town, Delta State, Nigeria

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ABSTRACT: The objective of this paper is to investigate on categorization of plastic waste (PW) generated for the conceptualization of pyrolysis plant development in Agbor Town, Delta State, Nigeria using selected 600 households to gather data. For high-, middle-, and low-income districts, this was further divided into 200 households each. The findings revealed that 600 households with 2328 people in high-, middle-, and low-income brackets produced a weekly total of 279.438 kg of household PW. Moreover, the weekly PW generated by 200 households each in Agbor town's high-, middle-, and low-income sectors were 39.496 kg, 32.569 kg, and 21.081 kg, respectively, whereas the weekly PW generated by households in these regions were 0.1054 kg, 0.1628 kg, and 0.1975 kg. In contrast, 0.0151 kg, 0.02326 kg, and 0.02821 kg of PWs were generated daily. The quantity of PW generated by persons and households were calculated, and this information can be utilized for the conceptualization of a pyrolysis plant development.

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Plastic pollution has a wide range of negative effects, from serious ecological disruptions to the aesthetic deterioration of landscapes (Orhorhoro *et al.,* 2016; Ahamed *et al.,* 2020; Orhorhoro *et al.,* 2023a). Plastic entanglement and consumption harm marine species, which has long-term effects on entire ecosystems (Eisfeld-Pierantonio *et al.,* 2022). Furthermore, a rising hazard to both terrestrial and aquatic life is posed by microplastics, which are produced when bigger plastic items break down and enter soils and water bodies (Ma *et al.,* 2020; Orhorhoro *et al.,* 2023b). With effects that go well beyond seashores and municipal landfills, plastic waste (PW) has turned into a global environmental problem (Evode *et al.,* 2021; Orhorhoro *et al.,* 2023c). Ecosystems, wildlife, and human health are all under risk due to the pervasive contamination caused by the exponential rise in plastic production and inadequate waste management techniques (Kumar *et al.,* 2021). Landfilling, incineration, gasification, and mechanical recycling are some of the current waste management techniques; nevertheless, each has important drawbacks (Orhorhoro and Oghoghorie, 2019). Because PW break down slowly and generate toxic leachates, landfilling adds to soil and water contamination. Although incineration lowers trash

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volume, it releases greenhouse gasses and dioxins into the atmosphere. Another waste-to-energy technique is gasification, which uses high-temperature processing to create syngas but necessitates strict operational controls to guarantee efficiency and reduce emissions. The diversity of PW and material deterioration during repeated cycles frequently limit mechanical recycling (Vaverkova, 2019; Shen *et al.,* 2020; Qureshi *et al.,* 2020). Pyrolysis is one of these methods that stick out as a creative and promising technique. Pyrolysis works in an oxygen-free atmosphere, which lowers the production of hazardous pollutants in contrast to gasification and incineration. In comparison to mechanical recycling, it not only transforms PW into useful products like char, syngas, and pyrolysis oil, but it also shows more flexibility in managing mixed and contaminated plastic streams. Furthermore, the method provides a mechanism to recover energy while reducing environmental effects and produces fewer greenhouse gas emissions than incineration (Nayak *et al.,* 2022). The process of pyrolysis, which breaks down organic compounds thermally without the use of oxygen, has drawn a lot of interest. Particularly encouraging is its capacity to transform PW into useful goods like chemicals and fuels (Papari *et al.,* 2021), like a circular economy where PW is seen as valuable resources rather than disposable annoyances by dissolving them into their constituent hydrocarbons (Armenise *et al.,* 2021; Hassan *et al.,* 2021; Cai *et al.,* 2023; Speißer and van Kleunen, 2023). However, the first stage and prerequisite for designing and building a pyrolysis plant for the control of PW generation is determining the amounts and availability of PW. The massive amount of solid garbage generated by Nigeria's population is expected to rise in tandem with the country's economic growth (Omole and Alakinde, 2013; Orhorhoro *et al.,* 2017). The production of waste is a necessary component of human activity that is impacted by social dynamics and economic advancement. One of the most urgent environmental issues facing the nation is the rise in waste generation and pollution brought on by the last 20 years' increases in per capita income, consumption, urbanization, and population, as well as a lack of adequate waste management infrastructure (Orhorhoro *et al.,* 2021). In addition to community activities, solid waste is produced by commercial, industrial, mining, and agricultural operations. Organic materials, plastics, paper, textiles, metals, rubber, and glass make up the majority of waste. In the nation, collecting mixed waste items without sorting them and then disposing of them at approved dump sites is the most popular waste management strategy (Orhorhoro and Oghoghorie, 2019). A formal system is used to collect less than 20% of the solid waste produced. The current estimates indicate harmful pressure on the environment, even though it is challenging to determine the precise numbers in the absence of authorities' garbage collection and disposal record keeping. Also, scaling a pyrolysis pilot plant for the management of plastic waste in the majority of Nigerian towns and cities is now challenging because, while numerous studies have estimated the amounts of solid waste generated by households and per person, there is no such data for PW generated daily or weekly by households or per person in Nigerian towns and cities. Consequently, the objective of this paper is to investigate the categorization of plastic waste generated for the conceptualization of pyrolysis plant development in Agbor Town, Delta State, Nigeria.

MATERIALS AND METHODS

Study Area: With roughly 67,610 residents, Agbor is the most populated city among the Ika. It is situated in Delta State's Ika South Local Government Area, which is in Nigeria's South-South geopolitical zone in West Africa. The Ika South Local Government Area of Delta State, Nigeria, has its headquarters in Agbor. The natives of Agbor town are Ika and speak the Igboid language, with a lot of Bini influences. The Nze na Ozo titles and other Nri cultural ties are among the inhabitants of Agbor, who were associated with the Kingdom of Nri and may have been established by settlers from that region. Agriculture and fishing have always been the main sources of food and income for the Agbor people. The latitude and longitude coordinates of Agbor town are 6.264092 and 6.201883, and it is located about 75 miles east of Benin City, Edo State, Nigeria. Renovations on the University of Delta (formerly known as the College of Education) in 2024 (Guardian, 2021) have led to Agbor being classed as a college town. The city was founded roughly 200 years ago, and since the mid-1900s, it has been expanding rapidly. It serves as the county seat for 25 communities, both big and small. The map of Agbor town and the surrounding area is displayed in Figure 1.

Materials Used: The following materials are utilized: a nose mask, a weighing balance, hand gloves, and containers labeled: other plastic waste (OPW), polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS). Plastic wasters that are generated are gathered using the containers.

Data collection and Sample Techniques: The data used in this study was gathered from households in the study area. To have a better understanding of the study area, we visited and looked at the different selected locations used in this study. Following the first visit, the family size of the household was noted. After another visit to the home, containers were distributed to 600 randomly chosen houses, 200 of which were high income, 200 of which were moderate income, and 200 of which were low income. Every week, the generated home PW were gathered, and a weighing balance was used to measure the amount produced both before and after sorting. Therefore, door-to-door collection was the strategy used to gather PW in the research locations. Equation 1 (Miezah *et al.,* 2015) was used to calculate the household-level PW rate and the daily PW generation rate.

$$PW = \frac{Total\ PW\ Generation\ in\ 7\ days}{7\ days\ \times total\ family\ size\ of\ households} \quad 1$$

Sorting Procedure: Table 2 displays the types of PW that were categorized by household. The PW was sorted into PET, HDPE, PVC, LDPE, PP, PS, and OPW at the collecting point.

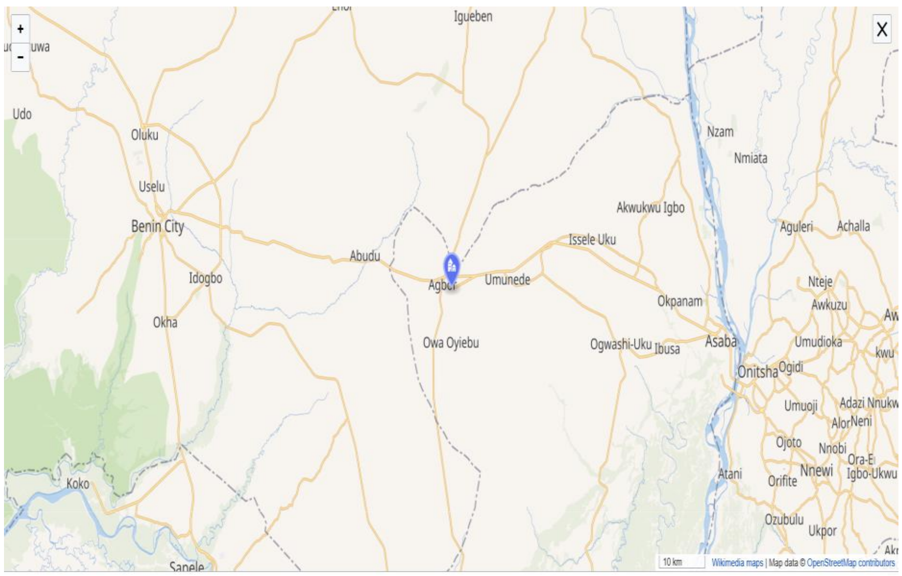

Fig.1. Map of Agbor Town and its Environs

Table 1: Standards for classifying Households according to Income Status (Miezah *et al.,* 2015 Oladipupo *et al.,* 2023)

SN	High Income (HI)	Middle Income (MI)	Low Income (LI)
1	Good road and drainage systems	Normal road and drainage systems	Destitute road and drainage systems
2	High level security	Moderate security	Poor security
3	Occupants own house	Both tenants and owners	Majorly tenants
4	High population density	Middle population density	Low population density
5	Reliable electricity	Moderate electricity	Unreliable electricity
6	Good community layout	Normal community layout	Poor community layout
7	Potable water supply	Unreliable water supply	Poor water supply
8	High level security	Moderate security	Poor security

Table 2: Classification of Plastic Waste Types Produced in Agbor Town

S/N	Plastic Waste Types	Components
1	Polyethylene Terephthalate (PET) Plastic	Bottle water, soft beverages, sports drinks, peanut butter, vegetable oil, and salad dressing.
2	High-Density Polyethylene (HDPE)	Bottles of milk and drink, bottles of detergent and shampoo, supermarket bags, containers for chemicals, recycling bins, and liners for core boxes.
3	Polyvinyl Chloride (PVC)	Blister packs (such as those for prescription drugs), vinyl flooring, tablecloths, plastic kid's toys, shrink wrap, clear food packaging, plumbing pipes, and kid's play mats.
4	Low-Density Polyethylene (LDPE)	Dry cleaning bags, bread bags, newspaper bags, vegetable bags, garbage bags, and sachets of pure water were among the items that generated LDPE waste, in addition to "paper" milk cartons and hot/cold beverage cups.
5	Polypropylene (PP)	PP waste was generated by yogurt containers, deli food containers, furniture, luggage, and clothing insulation.
6	Polystyrene (PS)	Packing peanuts, takeout containers, store meat trays, cups, and plates were the sources of PS garbage, often known as Styrofoam.
7	Others Plastic Wastes (OPWs)	Any garbage from plastic products that were not made from the six polymers listed above, like CDs, baby bottles, and headlight lenses, fell under this category of solid waste generated in Agbor.

Fig.2. Sorting and characterization of plastic waste in Agbor Town

Waste characterization: The technique of stratified random sampling (SRS) was used. A sampling technique based on population identification and characterization. Simply said, stratification is the process of assigning each member or element in the population to a single stratum by splitting the population into identical subgroups prior to sampling, as seen in Figure 3. The grouping process keeps going till the desired number is reached. The family members living in the home make up each strata.

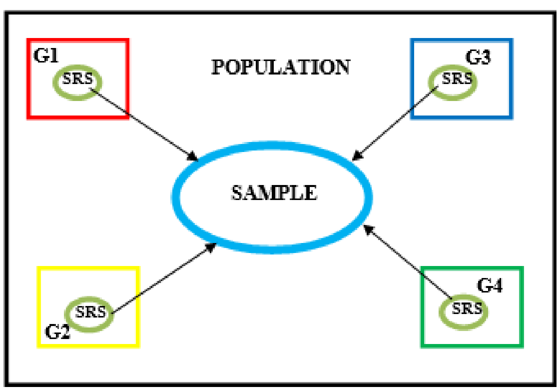

Fig. 3 Stratified Random Sampling

Where,G1 = Group 1 = First Household G2 = Group 2 = Second Household G3 = Group 3 = Third HouseholdG4 = Group 4 = Fourth Household………… G200 = Group 100 = Two hundred Household

The generated and sorted PW components were measured weekly as shown in Figure 2. For low-, middle-, and high-income earners, the PW weight was noted and recorded. After that, the determined PW weight is converted to percentages.

RESULTS AND DISCUSSION

Six hundred (600) households in Agbor town—200 high-income households, 200 middle-income households, and 200 low-income households—provided PW for the study in order to determine the quantity of PW produced in the town. The information gathered from the PW characterization will be used to design and construct a pyrolysis pilot plant. According to Figure 4, Agbor town's low-income area produces the least PWs generated per home, whereas the high-income area produces the most PWs generated per household. Each inhabitant of the household is different, though. Some homes have as few as two people living in them, while others have as many as seven. Therefore, Equations 2 and 3 were used to gain a better knowledge of the real PW generated by home and by person.

Fig.4. Results of Weekly Households PWsGeneration in Agbor Town

$$PW_{PHH} = \frac{PWG_{TH}}{T_{NH}} \quad 2$$

$$PW_{PP} = \frac{PWG_{TH}}{T_{NPH}} \quad 2$$

Where PW_{PHH} signifies plastic waste generation per household, PW_{GTH} implies total PW generated by households, T_{NH} indicates the total number of households, which was 200 days, PWpp indicates plastic waste generated per person, and T_{NPH} stands for total number of persons in the households.

According to the findings of the PW survey, 600 houses with 2328 people in high-, middle-, and low-income categories produced a total of 279.438 kg of household PW every week. Therefore, an average of 200 houses with 776 individuals in high-, middle-, and low-income groups produced 93.146 kg of household PW on a weekly basis. With the aforementioned figure, each home produced 0.4657 kg of PW every day. When broken down further, as

Figures. 5 to 7 illustrate, Agbor town's high-, middle-, and low-income neighborhoods produced weekly PW of 39.496 kg, 32.569 kg, and 21.081 kg, respectively as depicted in Figure 5. Additionally, as illustrated in Figure 6, the amount of PW generated daily was 0.0151 kg, 0.02326 kg, and 0.02821 kg, respectively, and the weekly amount per family in low-, middle-, and high-income areas was 0.1054 kg, 0.1628 kg, and 0.1975 kg. Moreover, as illustrated in Figure 6, the weekly and daily PW generated per person in low-, middle-, and high-income groups were assessed. According to the results, which are displayed in Figure 7, the weekly generation for low income, middle income, and high income was 0.02717 kg, 0.04197 kg, and 0.04197 kg, respectively. However, it was shown that the daily generation of PW per person for low-, middle-, and high-income groups was 0.00388 kg, 0.006 kg, and 0.00726 kg, respectively.

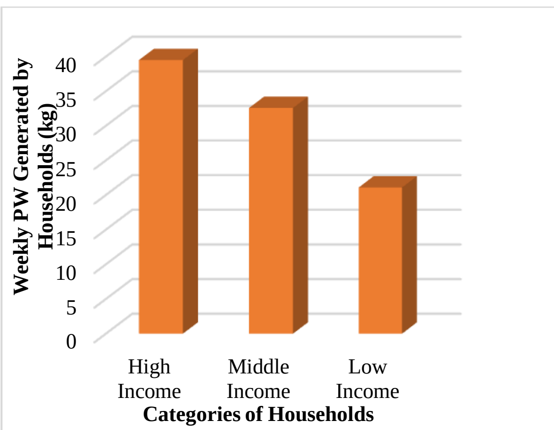

Fig 5. Results of Weekly PW Generated by all Households

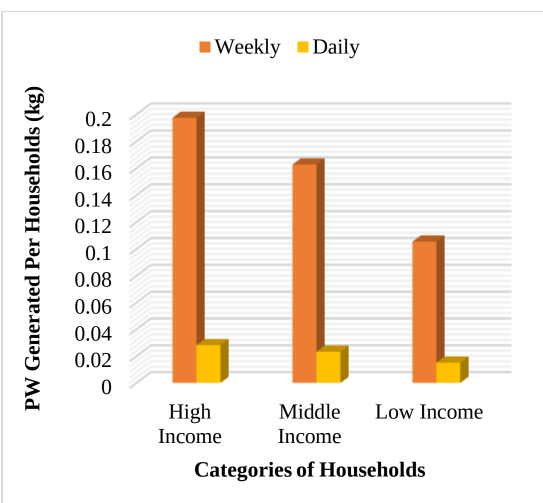

Fig 6. Results of Weekly PWs Generated Per Households

Previous studies revealed that high income produced the most PW and paper wastes whereas low income produced the fewest, as can be seen from all of the results gathered. The degree of economic growth, geographic location, culture, energy sources, and climate are the main determinants of solid waste (SW) composition, according to the literature (Orhorhoro *et al.,* 2017; Orhorhoro and Oghoghorie, 2019). Furthermore, consumption of inorganic materials rises while the proportion of organic materials falls when a nation's population grows and urbanizes (Sabkia *et al.,* 2018). Therefore, compared to inorganic fractions like paper, plastic, glass, and metal, which are more prevalent in the SW stream of high-income countries, low- and middle-income countries often have a higher percentage of organic matter in the SW stream. The fact that low-income areas have the largest organic waste proportion and high-income area have the lowest indicates that the estimated amount of organic waste and inorganic waste varies the income levels (Hoornweg and Bhada-Tata, 2012).

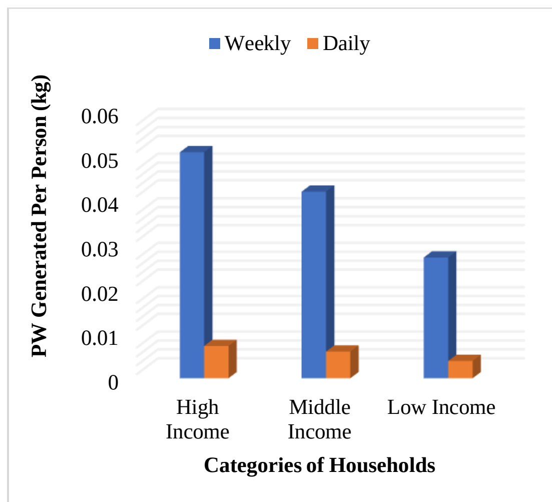

Fig 7. Results of Weekly PW Generated Per Person

As seen in Figure 8, HDPE has the largest amount (30%) by composition. Juice bottles, detergent bottles, chemical containers, recycling bins, and other items make up the majority of HDPE. Next in line is LDPE, which has a 26% composition and is primarily made up of rubbish bags, vegetable bags, and clean water sachets. With a composition of 4%, PVC PW is the least produced in the research area. The construction of a pyrolysis plant to control the generated PW is quite possible given the appropriate volume of PW produced in Agbor town. Because it can be thermally broken down by cracking events involving various polymeric chains or free radicals, plastic waste is an appropriate feedstock for pyrolysis (Witkowski *et al.,* 2016). The polymer categories that appeared alone or in different combinations within the chosen references were polyethylene (LDPE and HDPE), PP, PET, PS, PVC, and PUR; these polymer types were also categorized as MPW (mixed plastic waste). Furthermore, a great deal of research has been done on HDPE pyrolysis, showing that it is possible to produce large amounts of condensable products (pyrolysis oil) (Anuar Sharuddin *et al.,* 2016). PE, the most prevalent polymer in post-consumer plastic waste (Plastics Europe, 2021), accounted for 56% of the total, comprising both HDPE and LDPE, and was the subject of pyrolysis in the chosen references. PET, PS and PP came in second, third, and fourth respectively, at 13%, 11%, and 10%.

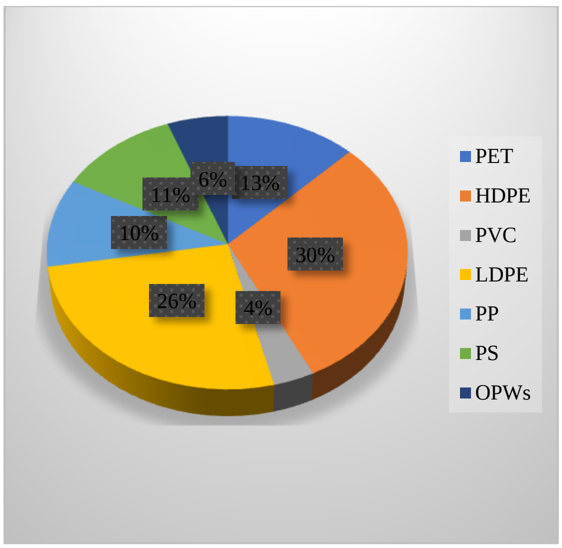

Fig.7. Percentage Composition of PWs Generated Per Households in Agbor Town

Conclusion: To improve the integration of the waste management system, the amount of PW produced in Agbor town was measured and described. Every major PW category is gathered, measured, and percentage composition determined. The survey found that houses in Agbor town produce a significant amount of PW. It is projected that six hundred families in Agbor generate 279.438 kg of PW per week. The PW rate generation in Agbor fluctuates according to income levels. HDPE plastic has the largest percentage of generated PW in Agbor town, followed by PET and PS plastic, according to the composition of the generated PW. Income typically has a significant impact in PW creation, even though population is a consideration to be taken into account for solid waste generation. Even though there were many low-income individuals in this study, the highest PW was produced by those with higher incomes. The study found that PW produced in the studied area had a high potential for recycling. Therefore, it is advised that PW be treated sustainably by recycling and thermochemical conversion, such as pyrolysis.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that could have influence the work reported in this paper.

Declaration of Data Availability: Data are available upon request from the corresponding author.

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