Challenges and Opportunities of Plastic Waste: A Case Study of Akure Metropolis.

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ABSTRACT

Environmental challenges that plastic waste poses have raised serious concern. Several post-used measures have been proposed to curtail the devastating effect of dumping plastic waste on landfill. Some of the measures proposed are recycling and waste to energy concept. However, recycling plastics may not be economically viable if adequate technique is not deplored in the process and choice of plastic to be recycled. In this study, plastic waste and waste management trend in Akure metropolis was assessed. The concept of energy to waste was brought to bear in exploring the opportunities and challenges of plastic waste. Two streams (stream I and II) of plastic waste were identified and it was proposed that recycling and pyrolysis technologies be used in the treatment of stream I and II plastic waste respectively. 25071 tons of plastic waste was estimated to have been generated in Akure, of which 58 and 42 percent were of stream I and II respectively. It was estimated that a total energy of 333.6TJ or 92667 MWh per year could be produced if all the stream II plastics were treated by pyrolysis technology. The net servings of US $1,212,719 and US $2,382,720 from recycling and pyrolysis technologies respectively, were estimated as economic benefits. Other benefits through the recommended technologies for plastic waste treatment were highlighted to include job creation, diversification of the economy and improvement in public health.

Keywords: Plastic waste, Akure metropolis, recycling, Pyrolysis and energy to waste.

1. INTRODUCTION

Plastic waste being one of the municipal solid waste (MSW) constitutes nuisance to our environment. Study have shown that plastic content of MSW in EU and US represent about 9.5 and 11.7 percent in weight (wt. %) respectively, representing a major proportion of the post-consumer waste stream [1]. Rigamonti et al. [2] gave a precise fraction of plastic in MSW. According to their study, plastic has definite proportion in MSW which make plastic waste a major waste in need of solution. Further report showed that plastics in MSW is made of Polyethylene terephthalate (PET), high density Polyethylene (HDPE), soft plastic or plastic films made of low density Polyethylene (LDPE). The remaining plastic material fraction is regarded as non-recyclable mixed plastic in which high proportion is non plastic. This assertion was further supported by [3] and [4].

With most of our daily needs being continually wrapped and packaged with plastic materials, the generation of plastic waste continues to be on the increase. Poor and inefficient waste management system in some remote areas give way to some of this plastic waste into the drainage systems, blocking the water ways and posing serious environmental challenge.

Plastics are polymer type of component with high molecular weight [5]. When this materials are disposed of as waste into the landfills, they become very difficult to decompose and keeps accumulating, thus posing serious environmental challenge. Basically, there are two types of plastics: Thermoplastics and thermosetting polymers.

Thermoplastics are plastics that do not change in chemical composition when heated and can be molded again and again. Examples of thermoplastics are: Polyethylene (PE), Polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC) and polytetrafluoroethylene (PTFE). While thermosets can be melted and formed only once, so that after solidification it will remain solid. The Polyethylene (PE) type of plastic have a wide range of inexpensive uses which include supermarket bags and plastic bottles. Polyethylene plastics may be further classified into three basic types: High-density polyethylene (HDPE), use for detergent bottles, milk jugs and molded plastic cases;

Low-density polyethylene (LDPE), use for floor tiles, shower curtains, sidings and clamshell packaging; and Polyethylene terephthalate (PET), use for water and carbonated drinks bottles, peanut butter jars, plastic film and microwavable packaging.

According to Govinda et al. [6], Plastic based material comes mostly from petroleum and natural gas. Some are composed of polymers of carbon and hydrogen with some oxygen, nitrogen and chlorine or sulfur [7].

Most plastic waste are disposed in landfills or are directly burned. This process has not solved the problems of plastic waste because the landfill process has not been able to decompose plastic waste. When it is burned at low temperatures, plastic waste will produce harmful compounds considered as carcinogens such as poly-chlorodibenzodioxin and poly-chlorodibenzofurans or simply called dioxins [6].

Many studies on plastic waste have proposed the concept of plastic to energy development. One of the methods in achieving this concept involves the use of pyrolysis in converting plastic waste to energy. Pyrolysis process involves the thermal cracking or degradation of polymeric materials by heating in the absence of oxygen. The process is usually conducted at temperatures between 350°C and 900°C and results in the formation of a carbonized char (solid residues) and a volatile fraction that may be separated into condensable hydrocarbon oil consisting of paraffins, isoparaffins, olefins, naphthenes, aromatics and noncondensable high calorific value gas. The proportion of each fraction and their precise composition depends primarily on the nature of the plastic waste and also on process conditions [8]. It is reported that 1 kg of plastic feedstock produces around 13 - 26.9% gases by weight [9]. Therefore, the produced gases can be used in boiler for heating or in gas turbine for the generation of electricity without any flue gas treatment [10].

However, for effective management and utilization of plastic waste, plastic recycling and plastic to energy development may be the way forward. Biron [11] had reported the need of diversity usage of material which has both technical and economic consequences in view of the cost involve in waste management. According to [12] and [13], plastic waste is recyclable and can therefore be used for the production of agricultural manure. Various researchers have exploited plastic wastes for potential energy generation as seen in many publications [14] and [15]. Plastic waste are now receiving attention for possible full scale economic activity as various environmentalist have emphasized plastic waste as a source of energy considering its recyclability and affordability [16] and [17].

Apparently, not all plastics that are recyclable are economically feasible to do so. Thus, adopting recycling method as a means of treating and managing plastic waste must be viewed critically. PE and HDPE plastics are recyclable but the later (HDPE) are often (in most cases) not economically viable to recycle due to the difficulties in sorting and the resources required in the process. Thus, a most suitable, sustainable and economically viable process must be fashioned out for effective management and utilization.

Consequently, this study identifies two streams (I and II) of plastics waste in Akure metropolis and proposes two technologies (Recycling and Pyrolysis) for the treatment and sustainable management of plastic waste in Akure metropolis.

Waste management in Akure

Akure is located in the south western region of Nigeria and lies about 7°25' north of the equator and 5°19' east of the Meridian. It is about 700 km Southwest of Abuja and 311 km north of Lagos State. The town is situated in the tropic rain-forest zone in Nigeria. Akure prides itself as Ondo State capital with a land area of 991 square kilometer (km^2) representing about 7.29% of the total land area in Ondo State. Akure has a population of 484,798 as of 2006 population census with an estimated population of 575,000 in 2011. Rural to urban migration for white collar jobs and better social amenities in Ondo State continues to increase. Akure serves as a trading centre for farm produce in Ondo State, where yams, cassava, maize, bananas, rice, palm oil, okra and pumpkins are grown. Cocoa is also grown in Ondo State for local market and export.

Municipal solid waste (MSW) in Akure poses serious challenges to the environment. However, Ondo State Government have demonstrated genuine effort in mitigating these challenges and have strived to make and keep Akure and its environs clean. Measures taken by the government include the establishment of Ondo State Waste Management Authority (OSWMA) and the subsequent initiation of Ondo State Integrated Wastes Recycling and Treatment Project (OSIWRTP). Waste management in Ondo state is controlled and managed by Ondo State Waste Management Authority (OSWMA). OSWMA is a government agency established in 1999 by the Ondo State Government. In deriving value from waste and at the same time protecting the environment, OSIWRTP was created out of OSWMA in June 2006 [18]. The project which is located along Igbatoro Road, Akure in Ondo state was commissioned by the then President of Nigeria, Chief Olusegun Obasanjo. With a staff strength of 84, OSIWRTP kick-started its initial operation in December 2006 with the mandate of: promoting a possible safe and profitable handling and recycling of generated waste within the state; designing and promoting policies and programmes to encourage source separation; development of pilot schemes to encourage and promote waste recycling; building local/national markets for recycled products; and collaboration with other appropriate government agencies to regulate the safe handling, disposal and treatment of different waste within the State. The expected result of this project is to mitigate soil, water and air pollution that is usually associated with the improper handling and disposal of wastes [18].

Waste pattern in Akure

The level of industrialization, socio-economic status of citizens and the kinds of commercial activities in various states of Nigeria determine the quantity and rate of solid waste generation [19]. Akure which was an agrarian community as at 1999 has now changed status. Some of it resident are now government official and business men and women. The status of life has changed to an average middle class society. The advent of small and medium scale industry have also led to increase economic activities within the town. This increased economic activity have reflected in the kind of waste generated. Adewumi et al. [20] understudied the composition of municipal solid waste in Akure. In the study, Akure metropolis was structured into three areas: Federal University of Technology (FUTA) Area, Market Area and Domestic Area. MSW composition in the three areas showed that plastic waste accounted for 10.73, 21.11 and 14 percent in weight (wt. %) of all the collected waste in FUTA Area, Market Area and Domestic Area of Akure respectively. See Table 1.

Table 1. Plastic waste composition in MSW of Akure metropolis

Plastic waste	**Areas in Akure Metropolis**		
	FUTA Area	Market Area	Domestic Area
Percentage composition (wt. %)	10.73	21.11	14

Source: [20]

Average weight percentage (wt. %) of plastic waste generated in Akure metropolis equals 15.28

In a study of waste to wealth by [18], it was reported that plastic waste accounted for about 12% of the total MSW collected in Akure. See Table 2.

Table 2: Summary of plastic waste composition in MSW of Akure municipal

Summary of waste composition in Akure Municipal								
MSW	Organic	Wood	Paper	*Plastics*	Metal	Glass	Textile	Sanitary Pads
Percentage composition (wt. %)	45	9	8	*12*	6	8	10	2

Source: [21]

Waste generation in Akure

Kum et al. [22] estimated that MSW generated in municipality alone as at 2005 was 0.32 kg/cap/day. With the increasing economic activities and the rise in per capita income of inhabitants, the amount of MSW in Akure is on the increase. Oloruntade et al. [21] presented the amount of MSW generation from year 2000-2010 (see Table 4). From Table 3, it can be seen that MSW in Akure increased gradually between 2000 and 2010.

Table 4. Municipal waste collected from 2000-2010 in Akure.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Waste Collected (t)	2881	3521	3163	3289	3291	3301	3175	4887	4925	7702	8538

Source: [21].

2. MATERIALS AND METHOD

The challenges of plastic waste and waste management trend in Akure metropolis was focused in this work. However, to capture the opportunities that may be derived from plastic waste, two plastic waste streams were proposed. Stream I consisting of PET plastics while stream II consisting of HDPE, LDPE, PP, PS PVC and PTFE plastics. Also, Recycling technology was proposed for the management of Stream I waste plastics while pyrolysis technology was proposed for the management of stream II waste plastics.

Plastic waste generation in Akure

The total amount of plastic waste generated in Akure metropolis was estimated to be 0.82 Kg/capita/day based on the waste generation trend of the resident (local population). It is estimated that Akure has a population of 698,048 in 2019. Based on the trend of plastic waste composition in MSW of Akure municipal, it was estimated that 12% of the total generated MSW in Akure was of plastic. A breakdown estimate of the total plastic waste generated reveal that stream I waste plastics (PET) accounted for about 58 percent and stream II plastics (HDPE, LDPE, PP, PS PVC and PTFE) was 42 percent of the total plastic waste generated.

Recycling and pyrolysis technology

The recycling process converts stream I plastics (PET) into raw materials at a cost benefit of US $83.4/ton for the production of new PET product. The pyrolysis process converts stream II plastics (HDPE, LDPE, PP, PS PVC and PTFE) waste plastic into liquid oil, char, and gases. An average yield of 0.8 kg of pyrolytic oil can be produced from 1 kg of mixed plastic waste. The average pyrolytic oil energy potential of 39.6 MJ/kg or 11KWh/kg as presented by [23], [24].

Anticipated benefit

The economic benefits were evaluated based on the cost savings on recycling stream I plastics (PET) and electricity generation potential from pyrolytic oil and gas. Electricity value of US $0.085/kWh was used in the analysis [24], [25], [26]. Plastic waste collection, plant operational and maintenance cost for recycling and pyrolysis technology were deducted from the gross savings of both recycling and pyrolysis technologies. All the savings are analysed in net savings and can be generated on an annual basis.

3. RESULT AND DISCUSSION

Plastic waste generated in Akure

Plastic waste generated in Akure as at 2019 was estimated based on the MSW generation of 0.82 kg/capita/day and 12% composition of plastic waste in MSW. Thus, total amount of MSW using 0.82kg/capita/day as the amount of generated MSW and 698,048 as the population, is estimated to be 208,926 tons and the total amount of plastic waste generated is 25,071 tons (at 12% composition of plastic waste in MSW).

Recycling opportunity

From the estimated amount of 25071 tons of plastic waste generated, fifty eight percent (58%) of 25071 tons which amounted to 14541 tons accounted for stream I waste plastics (PET). This figure represent a substantial amount of waste PET plastic available for recycling.

Energy generation opportunity

The pyrolysis process can convert stream II (HDPE, LDPE, PP, PS PVC and PTFE) plastic waste into pyrolytic oil that can be used as fuel to generate electricity. At an average yield of 0.8 kg of pyrolytic oil to 1 kg of mixed plastic waste, it is estimated that 8424 tons of pyrolytic oil can be produced if the pyrolytic process treats all the 10530 tons of stream II plastic waste. The energy potential of 39.6MJ/kg of pyrolytic oil gives the total energy generation potential of 333.6TJ or 92667 MWh per year. It was assumed that the efficiency of electricity generation plant from pyrolytic oil was 30%. This means that the plant can produce and deliver a total of 3.2 MW of continuous electricity supply in Akure throughout the whole year.

Economic benefit of recycling and pyrolytic technology in Akure

The economic benefit of recycling stream I plastic waste and the application of pyrolytic technology on stream II plastic waste for energy generation is shown in Fig. 1. The cost benefits were calculated based on the savings from recycling and electricity generation potential of pyrolytic oil. Recycling cost benefit of US $83.4/ton and energy generation servings of US $0.085 /kWh were used in the calculations. In Fig. 1, It can be seen that the net savings of US $1,212,719 and US $2,382,720 (Total of US $3,595,439) can be generated from stream I and II plastic waste through recycling and electricity generation potential of pyrolytic oil respectively.

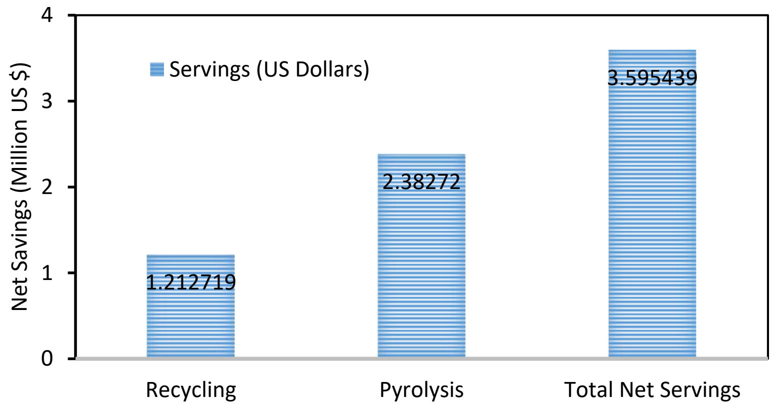

Fig. 1. Economic benefits of adopting recycling and pyrolysis technology in treating plastic waste

Apart from the economic and environmental benefits of recycling and electricity generation potential of plastic waste, other benefit through recycling and waste to energy concept include job creation, diversification of the economy from a civil service and agro based state into circular economy, public awareness enhancement and health improvement, reduction in the country's dependency on crude oil and saving millions of Dollars by avoiding health issues due to poor environment.

4. CONCLUSION

The case of plastic waste and waste management in Akure metropolis was studied. It was estimated that 25,071 tons of plastic waste was generated which accounted for about 12 percent of MSW in 2019. It was proposed that plastic waste be segregated into two streams where stream I contains PET plastics while stream II contains plastics of HDPE, LDPE, PP, PS PVC and PTFE types. Recycling and pyrolysis technologies were recommended for the treatment of stream I and II plastics respectively. It was estimated that a total energy of 333.6TJ or 92667 MWh per year could be produced if all the stream II plastics were treated by pyrolysis technology. The net servings of US $1,212,719 and US $2,382,720 from recycling and pyrolysis technologies respectively were estimated, totaling to around US $3,595,439. This amount was considered beneficiary among other benefit of recycling and pyrolysis technology, to include: job creation, diversification of the economy, public awareness enhancement on waste management, health improvement as well as clean environment.

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