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Recyclable resources from municipal solid waste: Assessment of its energy, economic and environmental benefits in Nigeria

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ABSTRACT

In this paper, the potential of recyclable municipal solid waste in each of the six geographical zones in Nigeria is presented with the aim of evaluating its energy saving potentials, economic and environmental benefits. The amount of recyclable materials in a stream of municipal solid waste is evaluated based on population model spanning from 2017–2036, waste generation model and recycling collection rate gathered from local literature, reports and publication from relevant institutions. The environmental advantage from recyclable municipal solid waste is conducted based on evaluation of its greenhouse gas emission potentials while the economic potential is estimated using cost adjustment factor method. Some of the results indicate that plastic is the most prominent recyclable waste in all the cities in the South-East, South-South and all the Northern parts of Nigeria. However, paper is the most available recyclable material in the waste stream of the cities in the South-West. The results also reveal that a total of 89.99 toe (1046.43 GW h) of energy could be saved per annum by recycling the recyclable waste materials rather than producing new products from the virgin materials. The saving in electricity could provide electrical power for about 9.8 million people based on available statistics of average electricity generation of 29,697,360.1 MW h and per capita electricity consumption of 107 kW h in Nigeria. Furthermore, a total of 11.71 million USD economic benefits could be realized which equivalent to about 16,562 jobs annually. The environmental assessment result indicates that a total of 307.364 ktons CO_{2eq} of GHG emission reduction could be achieved annually.

1. Introduction

In recent years, one of the greatest environmental challenges around the world is the exponential upsurge in the generation of municipal solid wastes (MSW) as a result of rapid population growth, urbanization, industrialization, economic development as well as changing consumption patterns. In the year 2012, the global MSW was approximately 1.3 billion metric tons and this amount is expected to rise to approximately 2.2 billion tons by the year 2025 (Rajaeifar et al., 2017) and 4.2 billion tons per year by 2050 (Nazmul -Islam, 2016). This unprecedented upsurge in MSW generation has put a lot of pressure on the existing infrastructure for waste management. Adequate treatment of this huge amount of waste being generated on daily basis is one of the biggest challenges faced by public authorities around the world (Lino and Ismail, 2017). However, the situation is more severe in Africa and other developing economies such as Nigeria where waste management is a herculean task. Indiscriminate dumping and burning of refuse along the road side or vacant space are the predominant methods of waste disposal in Nigeria; and in some cases the MSW generated is collected and conveyed to open dump sites, or collected and transported to landfill sites without methane capture where some informal recovery for recycling occurs and final treatment is by open incineration. This practice does not only pose great risk to social and public health but also endangers the ecosystem. It also distorts the esthetic of the environment; hence, pragmatic solution is required to bring this menace under control

MSW is a mixture of biomass and fossil fuel based materials. The biomass based (degradable) portion of MSW include materials such as food and animal wastes, yard waste, paper/cardboard, leather and wood among others. Fossil fuel based (non-degradable) components of MSW include glass, ceramics, plastic, rubber and metal (Ayodele et al., 2017b). Due to their physical and chemical compositions, the highly degradable components (such as food, human and animal wastes) give obnoxious odours after decomposition in the landfill. The non-degradable matters in the MSW are stable and can take years to decompose in the landfill. They only occupy space and therefore reduce the useful life of the landfill areas leading to waste disposal problem especially in the urban cities where land area for waste deposition is scarce. In some

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developed countries such as Denmark, Sweden and Germany, landfilling of certain types of waste such as combustible waste or untreated organic waste are now illegal (Leme et al., 2014) with the view to avoiding emission of free methane and other bad odour-causing gases. It is also to prolong the life of landfill areas. However, recycling as an alternative waste management option for waste is now recognised as an important approach to solving waste problem both in developed and developing world and has been recommended by researchers (Lino et al., 2010) to extend the useful life of landfills and some other value added advantages.

The term ‘waste’ is a subject of human appraisal as it could mean a different thing for different people. In general, waste is ‘unwanted’ for the person who discards it because the material has lost its use-value and is therefore thrown away (Bako, 2014a,b). However, to some people, waste is a valuable resource and is used as secondary raw materials (Nzeadibe and Adama, 2013). The use of waste material as an input to produce a new product is called recycling. In recycling, the so called waste material is a useful recourse. This process has the potential to provide some environmental, energetic, economic, and social benefits. Some of which include conservation of natural resources due to the use of less quantities of virgin (raw) material in manufacturing industries, reduction of energy and water consumption thereby reducing air and water pollution from the emission of greenhouse gas into the environment, job creation and income for waste pickers (scavengers), increasing the useful life of landfill areas and reduction of public spending for treating waste in the landfill sites (Lino et al., 2010; Lino and Ismail, 2017; Rajaeifar et al., 2017; Simonetto et al., 2013).

Recycling is the conversion of waste materials such as paper and cardboard, plastics, glass and metals into new and useful products with an economic value (Lino et al., 2010; Read, 1999). In this process, wastes materials are collected either from the source or final disposal site (landfills) and separated (sorted) according to type, compressed to reduce their volume, packed and transported to intermediate dealers or directly to the recycling plant where they enter again into the manufacturing chain (Lino and Ismail, 2017) to produce secondary materials or new products. Material recycling is generally categorised into either closed-loop recycling or open-loop recycling. In closed loop recycling waste products are recycled into material that is used for products of the same kind whereas open loop recycling occurs where waste products are recycled into material that is used for other kinds of products (Nakatani, 2014). For example, the reprocessing of polyethylene terephthalate (PET) plastic bottles into fibre is an open loop recycling process. For closed loop recycling, the recycled material and its virgin equivalent have the same quality and can be used to produce the same products. It is a general argument that the recycled product (such as recycled fibre) from open loop recycling system may be different in quality from its virgin equivalent (such as virgin fibre) (Shena et al., 2010). Another example is that recycled metal from “tins” cannot always be reused to machine cans (Diaz and Warith, 2006). This is however dependent on the recycling technology and the scope of such a comparison (Shena et al., 2010). Shena et al. (2010), confirmed that PET fibre produced by chemical recycling back-to-oligomers, mechanical and semi-mechanical recycling has a very similar quality to virgin fibre if a clean PET bottle source is used. In the context of this paper, it is assumed that all recycled materials have similar properties and quality as their virgin equivalent and considered to be used in place of the virgin inputs to manufacture new products. However, for the better functioning of recycling, it is very important to implement a wide system of selective collection in the cities, where recyclable portions in the MSW are segregated in homes and collected by the municipal selective collection system (Johnson et al., 2018). In Brazil, selective collection was introduced in urban cities in the 1980s with 1.2% of MSW selectively collected (Lino and Ismail, 2015). It is not clear as at now which state or region in Nigeria has adopted selective collection to enhance recycling program. Rather, collection of recyclables is informally left in the hands of scavengers. Recycling activities are very intensely driven by informal waste pickers in developing countries such as Nigeria (Bako, 2014a,b) and Brazil (Bako, 2014a,b; Lino and Ismail, 2017).

A number of studies have been conducted on the potential benefits embedded in waste recycling and its experiences in different countries around the world. Simonetto et al. (2013) assessed the energy savings in waste recycling using system dynamics model for metropolitan city of Rio Grande do Sul in Brazil. The model considered two scenarios and it was revealed that there were energy savings of 7500 MW h/month for positive scenario and 5800 MW h/month under current scenario. Lino et al. (2010) analysed the energy impact of waste recyclables in Campina metropolis, Brazil. The authors considered the use of selective collection as a tool for waste data gathering. It was estimated that the amount of recyclable material selectively collected was about 1% of the mixed solid waste collected. The authors also opined that with this amount of recyclable matter, an energy savings of 12,552 GJ/month (3487 MW h) could be realised which is equivalent to monthly electricity consumption of 4000 residences in Campina. This implies that recycling can greatly conserve energy. Seike et al. (2018) conducted a research on the PVC sash recycling system in Japan, and assesses the efficacy of the system in Hokkaido on environmental impact reduction, as well as its economic feasibility. Based on the result of these assessments, the efficacy of future PVC sash recycling systems on environmental impact and its economic feasibility was discussed. The authors revealed that CO_2 emissions from PVC sash recycling in Hokkaido using manually secondary separation in recycling plants was about 233 kg-CO2/ton. However for the machine separation, the CO_2 varies between 288–380 kgCO_2/ton. It was concluded that recycling of PVC sashes are generally economically viable in Japan. More studies on the benefit of waste recycling around the world can be found in (Lino and Ismail, 2013; Morris, 1996; Read, 1999; Themelis and Todd, 2004).

Some local authors have also conducted studies on MSW recycling in Nigeria. For example, (Otitoju, 2014) investigated the attitude of individuals toward recycling of municipal solid waste in Lagos, Nigeria. The author found that lack of awareness; inadequate infrastructural facilities and lack of involvement of public on policy formulation in waste management are the major impediments to waste recycling in Lagos. (Olukanni et al., 2014) did appraisal of the potential of the current state of solid waste management in a semi-urban city, its associated challenges and prospects in Nigeria. More studies on waste recycling in Nigeria can be found in (Kofoworola, 2007, Kofoworola, 2016; Sridhar and Hammed, 2014). However, studies on the assessment of the energy potentials, economic benefit and environmental advantage in terms of GHG emission reduction and fossil fuel displacement as well as social benefits of recycling of MSW in Nigeria are scarcely available. Therefore, this paper intends to assess the energy potential of recycling of recyclable MSW in some selected cities in Nigeria, its economic benefit, social inclusion in terms of employment creation as well as environmental advantages.

2. Recycling situation in Nigeria

Nigeria is the most populous country in Africa. By virtue of its large population, enormous amount of waste is generated resulting into huge waste management challenge. Recycling as an alternative waste management option has now been recognised as an important approach to solving waste problem in Nigeria (Bako, 2014a,b). At present, there is an obvious absence of formal recycling of municipal waste in Nigeria (Nzeadibe and Adama, 2013). Although waste recycling has formally been accepted in Lagos as an effective strategy towards waste diversion from landfills (Otitoju, 2014), yet it has not received adequate attention from the government (Bako, 2014a,b). Other cities in the country are yet to recognize recycling as an effective waste management. Waste recycling system is mainly carried out by informal sectors in Nigeria (Kofoworola, 2007; Nzeadibe and Adama, 2013) and this involves waste scavengers and itinerant waste pickers thereby achieving low but