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RECYCLING OF POLYURETHANE FOAMS: A STRATEGY IN WASTE MANAGEMENT AND CONTROL

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ABSTRACT

Recycling of polymer materials such as polyurethane foam is one of the needed strategies to combat the menace of pollution in our environment. Pollution has been a consequence of ever-increasing massive quantity of wastes generated from household and industrial activities, posing a global challenge to man and the environment. Recycling can also be used to conserve natural resources and reduce the consumption of fresh raw materials therefore having an overall effect on reducing unnecessary generation of waste from production processes. In Nigeria today, recycling of polyurethane post consumer product as a means of waste reduction in our society is still grossly underutilised. This paper examines the current trend in recycling as a means of waste management and focuses on various methods of recycling polyurethane foams considering their application(s) to the Nigerian situation.

Keywords: waste management, polyurethane, recycling, foams, polymer

1.0 INTRODUCTION

Waste management has been a major challenge in the Nigerian society as well as in most African countries owing to the dual problem of increase in waste generation as well as the poor management of such (Ezeronye, 2000; Akinkurolere and Franklin, 2005; Longe & Williams, 2006; Ossai, 2006). In Nigeria today , municipal solid wastes which are garbage generated by individuals, firms and organizations consisting of packaging, clothing, plastics, newspapers, batteries, furniture, ceramics, polyurethane foams, etc., have been mainly disposed by incineration and landfill as is the common practice in many other countries (Miller, 2000; Yanyin, 2002).

However, a lot of pollution problems are actually associated with this system of waste disposal in the sense that most dump sites actually pose health hazards to the entire populace in the vicinity.

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Nigeria is plagued by the existence of numerous waste dump sites dotting the urban landscape of the cities (WAMASON, 2008). The necessity of improving our waste management is more basic for many reasons ranging from that of community health to provision of essential amenities like potable water. Pollution of ground water needed to be avoided since over 75% of the Nigerian populace depend on surface or individually mined ground water as sources of drinkable water (WAMASON, 2008).

Much more, potential farmlands which could have been utilised alternatively to alleviate the problem of food shortage are being encroached upon day by day because of the increase in the wastes generated. Day to day open incineration of wastes generated has also caused pollution which has brought about the depletion of the ozone layer as a result of greenhouse gases emission. These forms of pollution resulting from poor waste management have been regarded as major factors leading to climate change all over the world. For these above and many other reasons a drastic step has to be taken to put the situation under control and protect the environment.

Consequently, in the developed world, concerted efforts have been directed towards minimizing wastes through reduce, reuse and recycling of post consumer products of various industries with collection centres for specific wastes like polyurethane foams and other post consumer products (PURR, U.S.A., 2005; Recyclers world, 2010: Yanyin, 2002). Therefore, it is more pertinent to judiciously minimize the quantity of waste generated by recycling in a relatively lower income country like Nigeria. This enables us to harness the attending benefits in term of the effects on community health as well as the process economics in the industry capable of indirect positive effect on poverty alleviation.

However, practices to reduce, reuse or recycle wastes have neither received widespread awareness nor implementation due to various reasons such as; lack of information on the need to minimize wastes, lack of information on the benefits of re-use, reduce and recycle (Akinkurolere and Frankling, 2005)

2.0 RECYCLING AS A METHOD OF WASTE MANAGEMENT

Recycling is one of the waste management measures that can be effective in the bid to conserve natural resources as well as save a deteriorating environment. Recycling has been defined as "the process through which materials previously used are collected, processed, remanufactured, and reused" (Schultz et al., 1995). In actual fact, waste is the other side of production because garbage/solid wastes discarded can be regarded basically as a waste of raw materials and energy in the light of recycling (George, 2007).

There are two basic types of recycling (Yanyin 2002; PURR, 2005; Behrendt and Naber, 2009);

- Primary or Close-Loop Recycling
- Secondary or Open-Loop Recycling

Primary or close loop recycling involves conversion of post-consumer waste materials into new products while secondary or open-loop has to do with converting the waste materials into entirely different products.

One of the advantages that can be derived when materials are recycled is the decrease in raw material input, because using recycled material will reduce the amount of new material needed to manufacture a new product, reducing about 20-90% virgin material consumption in primary recycling and up to 25% virgin material consumption in secondary recycling (Yanyin, 2002). Recycling also promotes significant reduction in quantity of resources such as utilities (water usage and energy) as well as in air pollution created during production processes, lowering green house gases emissions compared to that of virgin production.

Another advantage is that recycling, when used as a solid waste reduction and management strategy, minimizes the amount of wastes ending up at the dump sites and incinerators, hence, preventing useful materials from being wasted. Such materials include polyurethanes which can be reused even at the end of their original intended service life as furniture, shoe, car upholstery component, etc. They can still be as valuable at the point when they are ready to be discarded (CPI-ACC, 2012).

3.0 POLYURETHANES

Polyurethanes are major plastic materials with an annual world production capacity of over 12 million tons (Behrendt and Naber, 2009). They are polymers consisting of chains of organic units joined by urethane links. Polyurethanes can be formed by reacting a polyol (a polymeric alcohol with more than two reactive hydroxyl group per molecule) with diisocyanate or polymeric isocyanate (e.g. methylene diphenyl isocyanate, toluene diisocyanate) in the presence of suitable catalyst and additives.

Polyol + Diisocyanate ⟶ Polyurethane Polymer + Heat

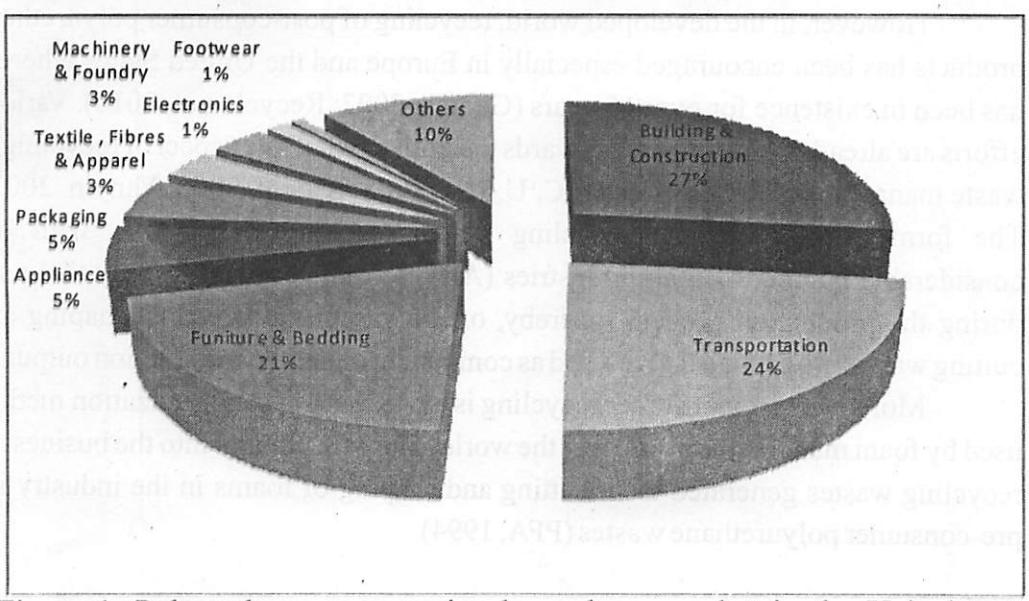

Figure 1. Polyurethane consumption by end use market in the United States (PURRC, 2005).

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They can also be made from renewable source (Ogunniyi et al.,1998).They are widely used in flexible and rigid foams, durable elastomers and high performance adhesives. Polyurethanes have found application in households as well as industrial products due to their various durable properties. Fig.1. shows polyurethanes consumption by end use in the United States market indicating polyurethane has found application in many industries. As the amount of waste generated is increasing day by day, polyurethane products have also found their way to the dump sites after serving their intended purposes, constituting waste disposal problem, much more, since they are not readily biodegradable (CPI-ACC, 2012).

3.1 Polyurethane Recycling as a Strategy of Waste Management

Significant portions of polyurethane foams are used in the production of furniture, car upholstery, in vehicle assembly factories, footwear and bedding industries, to name a few. They make up to 5% of all plastics and are made from petrochemicals (Knight, 2006). Waste generated from such uses sometimes comes as a mixture with other polymer materials such as nylon, polyester, cellulose, films, glass fibres which can be separated for the purpose of recycle. Waste-polyurethane scraps can be obtained from discarded materials by collection from soles of shoes, parts of toys, parts of furniture, parts of refrigerators, vehicle upholstery, etc. However, the recycling of the post-consumer polyurethane products still remains a challenge in most countries (Yanyin, 2002; Knight, 2006; Behrendt and Naber, 2009).

However, in the developed world, recycling of post-consumer polyurethane products has been encouraged especially in Europe and the United States where it has been in existence for over 15 years (George, 2007; Recycle.net, 2010). Various efforts are already being directed towards the utilisation of this aspect of recycling in waste management strategy (PURRC, U.S.A., 2005; Knight, 2006; Yanyin, 2002). The form of polyurethane recycling system existing in Nigeria, with our considerable number of foam industries (ADCB UAE, 2010) is mainly that used during the production process whereby, off polyurethane products, shaping and cutting wastes are ground and re-used as component of another production output.

Moreover, pre-consumer recycling is a popular waste minimization method used by foam manufacturers all over the world. They are already into the business of recycling wastes generated from cutting and shaping of foams in the industry i.e. pre-consumer polyurethane wastes (PFA, 1994).

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These polyurethane scraps have been successfully processed into useful products (Gebreselassie et al., 2001), thereby generating revenue, reducing raw material cost, and alleviating solid waste disposal problems. Recycled pre-consumer polyurethane wastes are made into bonded carpet underlay, they are used for the production of car seatbacks and head rest where the physical and mechanical properties are less demanding (compared to car seat cushion).

There is an international niche market for recycling both pre-consumer and post-consumer polyurethane foam scraps. Pre-consumer polyurethane sells for about 0.80USD / kg in South Africa, 0.2 - 0.7 USD / kg (recycle.net, 2010) in the United States, while Post-consumer PU scrap recently sells for about 0.24 Euro/ kg in Romania, Timis (recycle.net, 2010).

3.2 Some Research Works on Polyurethane Recycle

Many researchers have investigated various methods of recycling polyurethanes wastes so as to provide inexpensive raw materials for foam plants which is capable of improving the foam manufacturing process economics (Cannon, 2009). Polyol has been recovered from waste polyurethane by hydroglycolysis (Brawslaw and Gerlock, 1984). The polyol thus recovered was purified by liquid-liquid extraction. The process was claimed to produce a material capable of replacing as much as 50% of the virgin polyol used in high quality, low density polyurethane foam formulations with a reasonable process economics when no other market exist for the waste foam material. Conversion of waste polyurethane material was also done with the use of phosphonic acid diester as a degradation agent in the polyurethanes which was claimed (Troev,K., et al 1999) to be applicable for the preparation of useful polymers product with reduced flammability.

Another study (Gebreselassie et al., 2001) involved shredding of the polyurethane waste into fluff having a particle size of 0.25 -1.0 inch and moulding the material at elevated temperature and pressure such that the foam exceeds its glass temperature which occurred at 4000-8000 kN/ m^2 and 200 - 250°C. Then the hydrogen bonds in the hard segment of the polymer are broken under the elevated temperature and pressure. The bonds are then re-established on cooling sometimes leading to chemical arrangement of the polar groups in the hard segment. This method was claimed not to require the use of a binder. The physical property of the resulting material was varied by controlling the mould temperature, pressure and time so that the resultant product was tailored towards a particular application.

Hulrich et al, (in 2004), reported an emission free recycling process which involved heating the waste material with glycol mixture to obtain polyol that can be completely reused in the manufacture of rigid polyurethane.

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The process was claimed not to be sensitive to varying product mixes. Attempts (Kang, 2006) had also been made to use waste polyurethane as road and building construction materials. An elastic permeable pavement comprising waste-polyurethane chips for use on new roads and paving was prepared using a binder specially developed to secure the binding between an upper waste-polyurethane chip layer and a lower permeable concrete layer. The pavement was reported to have excellent strength, durability, elasticity and permeability suitable for sporting activities, walking and outdoor exercises.

Polyols obtained has also been used as components in the preparation of binders for composites of high textural and flexural strength (Behrendt and Naber, 2009). Datta and Rohn, in 2007, investigated thermal transitions and thermal stability of polyurethanes and polyurethane intermediates. However, some of the aforementioned methods are yet to be adopted in the industries, because they have not been cost effective. Polyurethane manufacturing companies are also rising up to the challenge. A process to glycolyze mixed polyurethanes has been developed by Troy Polymers, Inc.(PURRC,2005). The new polyurethanes produced from waste scraps retained most of the properties and functionality of the original materials.

Equipment manufacturers are already facing the challenges of designing new equipment and retrofitting the existing ones to recycle polyurethane wastes. Cannon has recently designed a new Cannon Filler Injection Kit (Cannon, 2009) which was claimed to reduce wear problems in existing machines and which can use up to 7% of the recycled material in the new polyurethane foam manufactured without affecting the mechanical and physical properties. Research efforts are also towards converting post-consumer polyurethane waste into valuable energy like electricity by modern technology incineration (CPI-ACC, 2012; WAMASON, 2008).

3.3 Main Methods of Recycling Polyurethane Foam

The major ways of polyurethane foam recycling are by mechanical and chemical processes as summarized in Figure 2 (Behrendt and Naber, 2009; Cannon, 2009; (CPI)- ACC, 2012). The mechanical recycling processes for polyurethanes include:

- Regrinding industrial and post-consumer flexible polyurethane foam into powders to produce new foam.
- Re-bonding into a variety of padding products, including recovered pieces of flexible polyurethane foam used in products such as carpet underlay and athletic mats.
- Adhesive pressing is a method which involves coating the polyurethane granules with a binder and then curing them under elevated temperature and pressure.
- Compression moulding involves subjecting the polyurethane granules to heat and pressure to produce rigid and 3-D parts, such as pump and motor housings.

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The chemical recycling processes include (CPI-ACC, 2012; PURRC, U.S.A., 2005):

- Glycolysis which is the method used to produce polyols from polyurethane scrap by reacting polyurethanes with diols at high temperatures.
- Hydrolysis (a reaction of polyurethane with water) is used to produce polyols and amine intermediates from polyurethane wastes. These intermediates can be re-used to produce other polyurethane components.
- Pyrolysis is the method which utilizes relatively high temperatures in oxygen-free environment to break down polyurethane and plastics into gas and oil which can also be used as fuels.
- Hydrogenation method is used to produce pure gases and oils through a combination of heat, pressure and hydrogen.

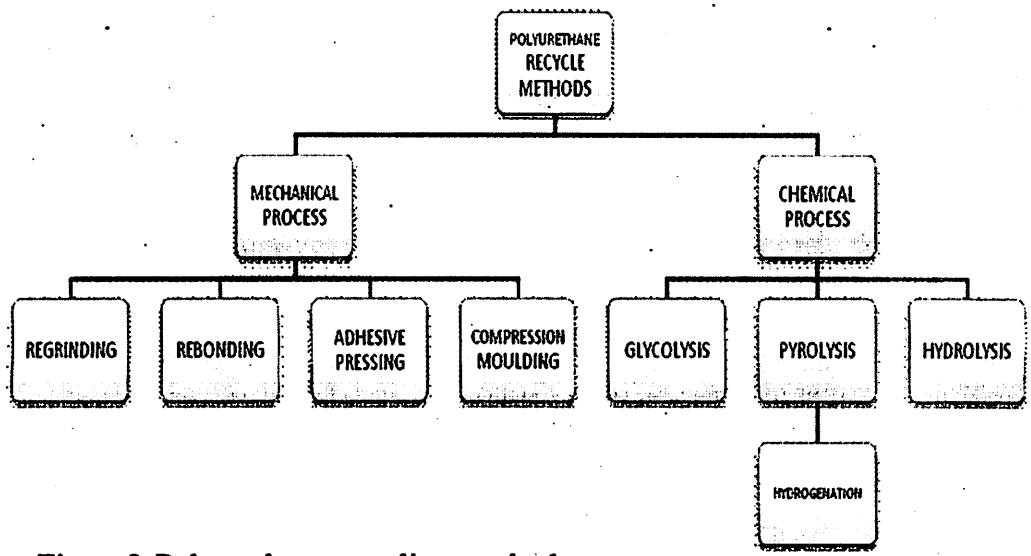

Figure 2. Polyurethane recycling methods

3.4 Uses of Recycled Polyurethanes Scraps

Polyurethane wastes can be used for special products based on the extra-ordinary properties that they exhibit by using the unique recycling procedures. The products generated have found application in (PFA, 1994; CPI, 2009);

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- Bonded carpet underlay
- Stuffing for pillows
- Packaging
- Sound insulation
- Mats
- Pump housing
- Paving material
- Automotive parts
- Tyre cover
- Car seatbacks
- Car head rest, etc

3.5 Lessons from Other Countries New Zealand, Sweden, Singapore, Canada, United States (CPI-ACC, 2009; George, 2007; Knight, 2006; Yanyin, 2002 ;)

Presently in the United States of America, polyurethane recycling business has been encouraged to the extent that the demand for flexible polyurethane foam wastes now exceeds the supply through domestic scrap recovery. They now engage in importation of scrap polyurethane from Europe thereby contributing to global polyurethane waste minimisation.

In the United States and Canada, recycled polyurethane markets database of contacts and companies who recycle polyurethane has been compiled to enable the trade to thrive more.

The post-consumer mattress-recycling programme has also been developed in the United States and Canada.

European markets are rapidly developing innovative uses for polyurethane wastes to provide high-value products for their consumers. Various research and development on waste management is going on around the globe on polyurethane recycling and other strategies of waste minimization. However presently in Nigeria there is no data base for the recycle of polyurethane as in some other countries mentioned. The form of recycle is limited to that of pre-consumer stage carried out in the polyurethane industries. Post-consumer recycle of polyurethane is yet to be promoted. Moreover, the poor waste collection system has not encouraged post-consumer recycle system. An effective polyurethane waste management in Nigeria should involve the promotion of the recycle of both pre-consumer and post-consumer polyurethane waste for re-use and export.

Energy recovery from polyurethane wastes is a potential benefit of effective polyurethane waste management which is yet to be harnessed in Nigeria .This can be useful especially in the generation of electricity.

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The post-consumer polyurethane waste can find applications to meet specific Nigerian needs if enough attention is given to it. Moreover, effective polyurethane waste management in Nigeria should minimize the use of post-consumer polyurethane wastes for land fill and incineration (see Fig 3).

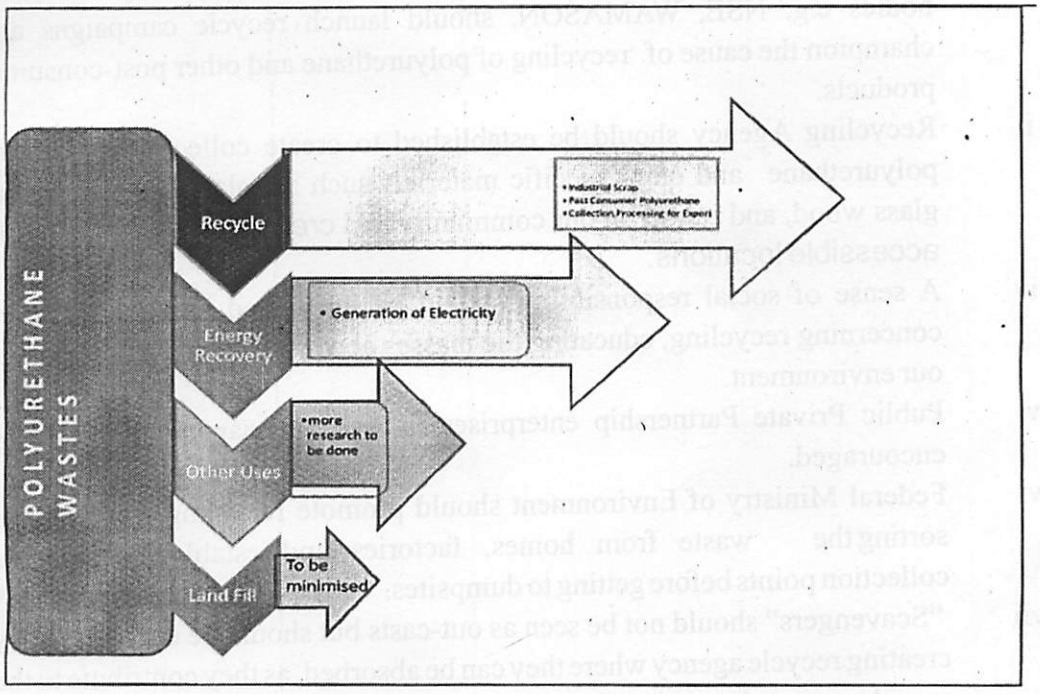

Figure 3. Effective Polyurethane Waste Management

4.0 CONCLUSION

More efforts should be made by the Government through the Federal Ministry of Environment towards having a cleaner Nigerian environment as we strive to achieve vision 20:2020. Nigeria as the giant of Africa should take a leading step and set the pace for others to follow in this bid to rescue our environment through emphasis on recycle, borrowing a leaf from UK., U.S. A., Canada, Singapore, Sweden and other countries.

With the Nigerian population and increasing urbanization, for the problem of poor waste management that bedevils Nigeria and most of the African countries to be overcome, all hands should be on deck in order to achieve a sustainable development in waste management. If recycling of post-consumer polyurethanes and other materials are given the much desired attention, recycling will be one of the appropriate strategies to improve waste management as well as to combat the problems of pollution and global warming in Nigeria.

5.0 RECOMMENDATIONS

i Some of the beneficial programmes/measures put in place to manage waste in Nigeria, already launched by the Federal Government should be reviewed and reactivated to emphasize recycling of polyurethanes and other post consumer products.

ii Government and Non-Governmental Organizations (NGOs), professional bodies e.g. NSE, WAMASON, should launch recycle campaigns and champion the cause of recycling of polyurethane and other post-consumer products.

ii Recycling Agency should be established to create collection points for polyurethane and other specific materials such as; plastic, paper, metal, glass wood, and rubber in our community and creating recycling bins in accessible locations.

iv A sense of social responsibility should be inculcated into the citizenry concerning recycling, educating the masses about the attending benefits to our environment.

v Public Private Partnership enterprises in waste management should be encouraged.

vi Federal Ministry of Environment should promote recycling from source, sorting the waste from homes, factories and establishment or at collection points before getting to dumpsites.

vii "Scavengers" should not be seen as out-casts but should be encouraged by creating recycle agency where they can be absorbed, as they contribute to the recycle process by sorting the rubbish before it gets to the dumpsites.

viii Useful and accessible waste generation and recycling data should be made available through more research. This is needed to monitor the progress of waste management in Nigeria.

ix Data base of existing recycling agents in Nigeria should be created.

X There should be a review of relevant legislations, policies and regulation in order to promote recycling (of polyurethanes and other materials) as an important strategy in achieving effective and sustainable waste management and control in Nigeria.

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