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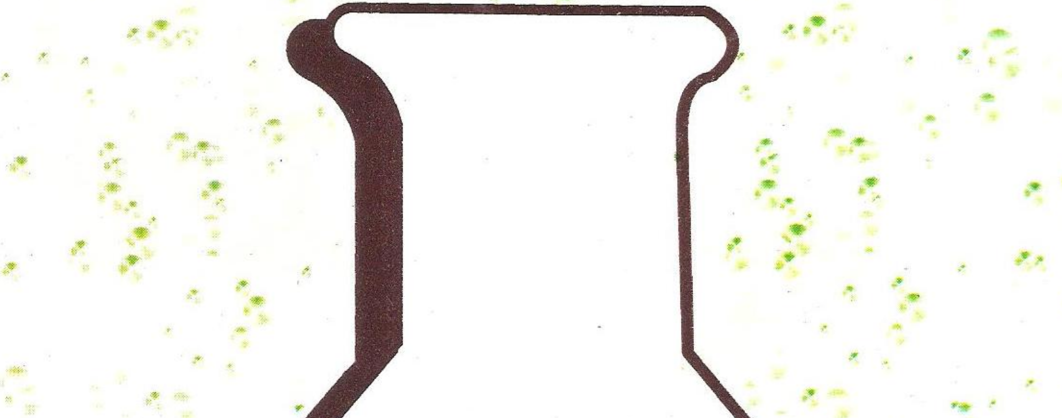

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Thermal Cracking of Low Density Polyethylene (LDPE) Waste into Useful Hydrocarbon Products

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ABSTRACT

Waste low density polyethylene film (table water sachets) was converted into solid, liquid oil and gaseous products by thermal process in a self- designed stainless steel laboratory reactor. The waste polymer was completely pyrolized within the temperature range of 474 – 520°C and 2hours reaction time. The solid residue obtained exhibits the characteristics of grease which is totally dissimilar to the plastic characteristics of the waste polymer fed into the reactor. Liquid fuel oil is rich in paraffins and olefins containing C_8-C_{24} hydrocarbons. The gaseous product (suspected to be lower hydrocarbons in the range C_1-C_4) was eluted without collection. The liquid oil product was analyzed by GC/MS technique.

Keywords: Low density polyethylene, Pyrolysis, Thermal cracking

INTRODUCTION

One of the important advantages of plastics is their extreme durability and this in turn contributes the greatest disadvantage from the perspective of environmental science as they degrade slowly if at all (Fried, 2003). The rising volume of plastics consumed annually the world over and their efficient disposal is becoming a huge problem even for advanced countries where there are standard regulatory systems for wastes disposal. In developing countries where there are no such strict regulations, the wastes accumulate and affects the aesthetic features of a country's topography by giving it an un-kept appearance as well as providing habitats for different organisms that can have harmful effects both on their immediate and remote environments. In view of these, there is the need to find a way of at least managing plastic wastes efficiently in the short-term if not a permanent solution to their disposal problems.

The methodologies commonly explored for reducing or disposing of plastic wastes include; source reduction, incineration, biodegradation and recycling. Out of all these methods, recycling attracts the most attention because of the potentials of the products obtainable from the process. Recycling involves the conversion of plastic wastes to other useful products through mechanical or chemical processes. The mechanical recycling process involves a number of operational steps that invariably leads to reprocessing into new plastic goods however; it is mainly restricted to thermoplastics because thermosets cannot be remoulded by the effect of heat (Aguado and Serrano, 1999). Another problem with mechanical recycling is that recycled polymers exhibit lower properties and performance than the virgin polymers, and are useful only for undemanding and lesser value applications (Ylä-Mella, 2005).

The chemical method of recycling plastics is pyrolysis which is a tertiary or feedstock recycling technique capable of converting plastic wastes into fuels, monomers, or other valuable materials by thermal and catalytic cracking processes as well as treatments with chemicals. This method can be applied to transform both forms of plastics into high-quality fuels and chemicals. Moreover it allows the treatment of mixed as well as unwashed plastic wastes (Ylä-Mella, 2005) and thus has great potentials for heterogenous plastic wastes that cannot be economically separated (Scheirs and Kaminsky, 2005). In this way, it is possible to obtain a predominantly liquid hydrocarbon product with potential for use as a fuel or a refinery feedstock (Low *et al.*, 2001). There has been some considerable advancement in polymer cracking in the last decade and polyethylene has been targeted in particular as a potential feedstock for fuel (gasoline) producing technologies (Achilias *et al.*, 2012). The present study was conducted with the intent of determining the effectiveness of the pyrolysis process of the waste polymer in a self designed laboratory reactor that would allow for such conversion.

EXPERIMENTAL

Sample Collection and Preparation

Waste low density polyethylene (table water sachets) were collected from household and municipal wastes after which they were washed, dried and shredded to smaller pieces to ensure quicker conversion.

Pyrolysis of LDPE

The experiment was carried out under an inert atmosphere of Nitrogen in an air tight cylindrical reactor made from stainless steel (length 210mm and 22mm inner diameter) fitted with connecting pipes leading in to and from it for conveyance of necessary gases and product collection respectively. A condensing flask that was dipped in ice and maintained at 4^{o}C to ensure minimal loss of gaseous products was attached to the outgoing pipe. The reactor was stacked with 100g of waste low density polyethylene film (shredded table water sachets) and heated after an initial purging with nitrogen for 30 minutes. The temperature was allowed to rise gradually and evolution of gases was observed at 474^{o}C (45 minutes into the reaction) after which oil droplets started collecting in the condensing flask. The collection proceeded for another 1 hr 5 minutes after which the reaction was discontinued when evolution of gases stopped. The overall temperature range for the experiment was between 474-520^{o}C which were the temperatures at the first visual sign of evolution of gases and at the end of the experiment respectively. The heat was removed and the content which was an opaque, light (not thick) liquid was overturned into a metal plate where it rapidly cooled into a grease-like substance that weighed 34.893g. The oil was found to be 22g after weighing and the weight of the gaseous product was estimated by material balance to be 43.107g. The grease remained soft and stains the finger when touched even after several weeks. The oil was taken for analysis.

GC/MS Analysis of the Liquid Product

The liquid product was characterized by Gas Chromatography – Mass Spectrometry which produced a chromatogram of 23 peaks that was used to identify the different components present in it.

RESULTS AND DISCUSSION

Products of Thermal Cracking of HDPE

The three products obtained from the experiment as summarized Table 1 were solid residue, liquid oil and gaseous product, highly combustible, confirmed with flame tests (Ademiluyi and Akpan, 2007) which according to (Bertolini and Fontainel, 1987) were to be expected except that the solid residue from this experiment was more of a grease as opposed to the wax suggested by them. The gaseous product was eluted without collection but its percentage yield was determined by material balance (Low *et al*, 2001 and Osueke and Ofondu, 2011). The percentage yield in ascending order is liquid < solid < gases as can also be seen from above. The gases were light as they were non-condensing at 4°C, highly flammable with a characteristic "burnt smell" while the liquid product was oily and slippery with appearance falling in the range of diesel and petrol but of an entirely different odour. The residue was a shiny black and sticky material that was identical to a jelly with characteristics similar to those of commercially available greases.

Table 1. Yield of Products of Thermal Cracking, Wt(%)

Products	Yield Wt(%)
Liquid	**22.00 ±0.35**
Gas	**43.11 ±0.40**
Solid	**34.89 ±0.31**

Result of GC-MS Analysis of Liquid Product

The chromatogram obtained from the GC-MS analysis of the liquid product obtained is presented in Fig 1

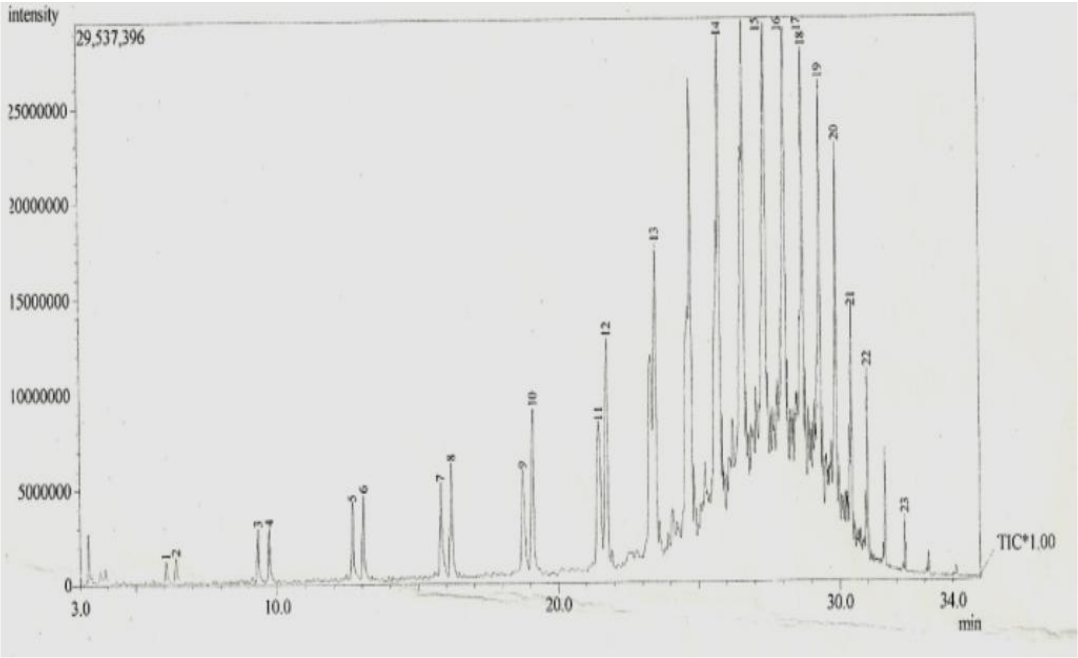

Fig. 1: GC-MS Analysis of the Liquid Product

The height of the peak under which each of the identified compounds appears is measured as a fraction of the total height of the peaks multiplied by 100 to obtain the percentage yield attributed to each of them and these are presented in Tables 2 and 3 respectively.

Table 2: Hydrocarbons and their Relative Abundance in the Liquid Product

Hydrocarbons	**Relative Abundance (%)**	**Suggested Petroleum Fraction**
C_8-C_9	**8.69**	**Petrol (Gasoline)**
C_{10}-C_{15}	**65.22**	**Kerosene**
C_{16}-C_{24}	**26.09**	**Diesel (Gas Oil)**

Table 3: Percentage Abundance of Paraffins and Olefins in the Liquid Product

	C_8-C_9	**C_{10}-C_{15}**	**C_{16}-C_{24}**
Paraffins	**5.88**	**58.82**	**35.30**
Olefins	**16.7**	**83.3**	**-**

The oil was characterized by the GC-MS analysis and found to be in the range C_8-C_{24}, rich in aliphatic hydrocarbons as reported by Williams and Williams, 1999, especially paraffins and olefins as was also the case in the investigation carried out by Achilias *et al.* 2008. The overall percentage yield of olefins and paraffins in the oil are 26.09 and 73.91 respectively which indicates a high level of saturation in the product. The distribution was such that most of the compounds were straight chain hydrocarbons, only a few were branched. The composition of the oil is similar to those already reported in literature; C_6 -C_{15} (Achilias *et al.*, 2008), C_9 – C_{25} (Low *et al.*, 2001), C_3 – C_{28} (Moinuddin *et al.*, 2012) and C_3 – C_{38} (Ademiluyi and Akpan, 2007). In these reports, the oils were found to be identical in composition to existing hydrocarbon fuels; petrol, kerosene and diesel oils found in the refineries and thus similar to the liquid product obtained from this investigation.

CONCLUSION

Waste low density polyethylene was successfully cracked into solid, oil and gaseous products in a self designed laboratory stainless steel reactor. The oil obtained is rich in aliphatic hydrocarbons and its compositions could be compared to existing hydrocarbon fuels. This could provide a non-destructive way of converting polyolefinic wastes into desirable products;

burnable gas products, energy loaded liquid fuel products and solid grease products that can find applications as product grease or solid fuel.

REFERENCES

Achilias, D. S., Antonakou, E., Roupakias, C. Megalokonomos, P. and Lappas A. (2008). “Recycling Techniques Of Polyolefins From Plastic Wastes” *Global NEST Journal*, 10(1):114-122.

Achilias, D. S., Andriotis, L., Koutsidis, I. A., Louka, D. A., Nianias, N. P., Siafaka, P., Tsagkalias, I. and Tsintzou, G. (2012). “Recent Advances in the Chemical Recycling of Polymers (PP, PS, LDPE, HDPE, PVC, PC, Nylon, PMMA)”, Material Recycling - Trends and Perspectives, Dr. Dimitris Achilias (Ed.), ISBN: 978-953-51-0327-1, InTech,DOI:10.5772/33457.http://www.intechopen.com/books/material-recycling-trends-and-perspectives/recent-advances-in-the-chemical-recycling-of-polymers. Accessed on 12/06/2013

Ademiluyi, T. and Akpan, C. (2007). “Fuel gases from pyrolysis of waste Polyethylene sachets” *J. Appl. Sci. Environ. Manage*. 11(2):21 – 26.

Ademiluyi, T. and Akpan, C. (2007). “Preliminary evaluation of fuel oil produced from pyrolysis of waste water sachets” *J. Appl. Sci. Environ. Manage*. 11(3):127 – 131.

Aguado, J. and Serrano, D. P. (1999). “Feedstock Recycling of Plastic Wastes”. (Series Editor J.H. Clark), The Royal Society of Chemistry, Cambridge.

Bertolini, G. E. and Fontaine, J. (1987). “Value Recovery from Plastics Wastes by Pyrolysis in Molten Salts” Conservation and Recycling. 10(4):331-343.

Fried, J. R., (2003), Polymer Science and Technology, second edition, Prentice Hall, New Jersey. pp 276-277.

Low, S. L., Connor, M. A. and Covey, G. H. (2001). “Turning Mixed Plastic Wastes into Useable Liquid Fuel”. Paper Presented at the 6th World Congress of Chemical Engineering, Melbourne, Australia, 23-27 September, 2001.

Moinuddin, S., Mohammad, M. R. and Muhammad, S. R. (2012). “Thermal Conversion of Polymer Wastes (LDPE) into Hydrocarbon Diesel Fuel without Cracking Catalysts” *Int. J. Pure Appl. Sci. Technol.*, 11(2):36-44.

Osueke, C. O. and Ofondu, I. O. (2011). “Conversion Of Waste Plastics (Polyethylene) To Fuel By Means Of Pyrolysis” *International Journal Of Advanced Engineering Sciences And Technologies* 4(1):21 – 24.

Scheirs, J. and Kaminsky, W., (2005). “Preface; Introduction to Feedstock Recycling of Plastics” *Feedstock Recycling and Pyrolysis of Waste Plastics*; http://media.wiley.com/product_data/excerpt/27/04700215/0470021527-1.pdf, 02/05/09

Williams, P.T. and Williams, E. A. (1999). “Fluidised bed pyrolysis of low density polyethylene to produce petrochemical feedstock” *Journal of Analytical and Applied Pyrolysis*, 51(1-2):107–126.

Ylä-Mella, (2005). RECYCLING OF POLYMERS *J. 480360S Environmental Catalysis*,; www.oulu.fi/resopt/PlastRec.pdf , 13/04/09.