RECYCLE OF POLYETHYLENE TETRAPHTHALATE WASTE

P. Oghome
Department of Chemical Engineering
Federal University of Technology, Owerri, Imo State
Email:ify_pros@yahoo.com.

ABSTRACT

The recycling of polyethylene tetraphthalate (PET) was carried out to determine its feasibility and economic viability. The recyclate was characterized to determine its intrinsic viscosity (I. V.), melting point and viscosity average molecular weight in order to ascertain the extent of polymer degradation due to weathering and heat homogenization. It was found that weathering induced degradation resulted in an I.V drop of 0.035dl/g while homogenization was responsible for a further I. V. drop of 0.05dl/g and a consequent viscosity average molecular weight (M_v) drop of 3000g/gmol. A final I. V drop of 0.68dl/g was observed which was converted to an M_v of 29407g/gmol. This result was close enough to that of virgin resins and can be reused, when mixed with virgin resins for blow molding. It can also be used for the production of film and fiber.The objective of this work is to reduce the amount of non-biodegradable substance in our environment, to determine the effect of degradation on post consumer PET and providing an alternative source of raw material at reduced cost for PET consuming industries.

Keywords*:* Recycling, Homogenization, Weathering, Intrinsic Viscosity, Non-biodegradable, Reclamation.

INTRODUCTION

The environment can be generally defined as the entire range of external influences natural and man made that can impinge on the life support system essential for health and survival. The quality of our environment over the years has declined as a result of various human activities. Over the years there has been a growing concern of the issue of environmental degradation which prompted the establishment of environmental protection agencies. The developing countries are plagued with poverty and also gave little attention to environmental issues. One of the challenges is the management of municipal waste. Waste is divided into domestic, industrial, and agricultural, contents of domestic dustbins are referred to as municipal waste, which is generated everyday all over the world and ever increasing, hence the need to devise an effective and environmentally friendly municipal waste management programme. One of the ways is focus of this study that is method of recycling.

Recycling for the purpose of waste management can only be carried out on the components of solid waste that are non-biodegradable. These components include plastics, glass, metals and their alloys, ceramics. This work is centered on plastic recycling. Not all plastic are recyclable. Focus on plastic recycling is primarily on the thermoplastic component of the plastic waste stream. This represents about 75 – 80% of all plastics manufactured (World Resource Foundation, 2000).Polyesters belong to the broad generic class of organic high molecular weight condensation polymer and are

characterized by ester groups distributed either regularly or randomly along the main molecular chain (Billmeyer, 1962). Polyethylene Tetraphalate (PET) is the most common thermoplastic polyester and is useful for packaging, film, sheet, coasting and bottles.

In the 1970's the industry learned that they would need a high molecular weight PET to serve the container market that is a polymer with an intrinsic viscosity greater than 0.7dl/g (Milgrom, 1992). The melting point of virgin, fully annealed PET is 280^0C, but most PET products melt at 255 – 265^0C due to reduced crystallinity resulting from the addition of impurities in the polymer matrix (Droshner and Makronid, 1980). Glass transition temperature T_g is a temperature at which a polymer undergoes a phase change. The glass transition temperature of commercially available PET material is between 67 and 140^0C. The value depends on polymer purity, degree of crystallinity and molecular weight. According to Progelhof and Throne, 1993, glass transition temperature of PET is averagely 60^0C. PET with a viscosity average molecular weight M_v of 30000 – 40000 are suitable for injection moulding giving rise to better impact strength. The impact strength of thermoplastic polyester increases with increasing molecular weight (Brozenick, 1986). The intrinsic viscosity of polyesters in a phenol tetrachloroethane (60:40) mixture varies from 0.45 – 1.2dl/g, depending on the use. Commercially PET products have intrinsic viscosity from 0.45dl/g for certain film and textile fibre application to as high as 0.9dl/g for blow moulded soft drink bottle which correspond to M_v of 1500v and 4500_v respectively (Brozeinck 1986). The objective of this work is to reduce the amount of non-biodegradable substance in our environment, to provide an alternative source of raw material at reduce cost for PET consuming industries and also to determine the effect of degradation on post consumer PET as it applies to the physical properties and performance characteristics of the recycled materials.

EXPERIMENTATION

The experimental part of this work was divided into two sections. The recycling of post consumer waste PET and characterization of recycled PET.

Recycling of Post Consumer Waste PET

This comprises collection, sorting and reclamation. Several post consumer PET beverage and water bottles were collected from a number of house holds and some from refuse dump. The PET vessels were then sorted manually to remove sand and other unwanted particles. Each bottle sorted was examined for society of plastic industry (SPI) code "No. 1" indicating that the plastic was PET. The PET bottles were further sorted for non-PET parts such as the corks, labels and base cups. The bottles were washed with ordinary water and dried under sunlight.

Reclamation

The sorted bottles were made into flakes by cutting them into small sizes with a pair of scissors. The sizes were further reduced by the use of a granulator to about 2cm. This was done to reduce volume and size of the bottles to facilitate uniform heat distribution during polymer homogenization. The flakes were washed with warm water at 75^0C to remove impurities and leftover label gum and rinse with ordinary water.It was then sun-

dry with the aid of an electric fan to prevent degradation high sunlight and incomplete drying. and incomplete drying.

Homogenization which is the application of heat for melting and proper mixing was carried out by putting the flakes in a glass beaker and heated on a hot plate. The heating was continued till the flakes had melted completely and mixed. After homogenization, the beaker was placed in cold water bath for the reclaimed PET to cool.

Characterization of Reclaimed PET

Determination of Melting Point

Two thin strips of the polymer measuring about 0.5cm in width and 2cm in length were peeled off the reclaimed PET using a razor blade. They were then placed across each other to form a cross on a glass slide. The arrangement was covered with another glass slide and transferred to the heating mantle of a hot stage microscope. The intersection of crossed polymer was observed through the microscope as the polymer was heated. At melting point, the hither to district intersection became blurred and varnished as the molten polymer mixed. At this point, the temperature was read from the microscopes digital display. The procedure was repeated for both the flake and reclaimed PET material.

Determination of Intrinsic Viscosity

To determine the intrinsic viscosity, 5g of reclaimed PET was weighted into a reagent bottle to which was added 1litre of phenol -1, 2, 2 – tetrachloroethane. 100ml of the same solvent was introduced into another bottle as a control. The solution and the solvent alone contained in the bottle were placed in an oven at 120^0C for one hour. After one hour, the bottle was cooled in a water bath to room temperature, 25^0C. The content of the solution bottle was filtered to remove any undissoved PET. The flake PET was also prepared in the same manner. 100ml of both solutions were pipette into a conical flask to determine their intrinsic viscosity. The intrinsic viscosity was determined by Ostward Capillary viscometer method. A stop watch was used to note the flow of time for each sample. Three different readings were taken for each sample and the mean time was calculated.

From the mean times "t" for solution flow time and "ts" for pure solvent flow time, the intrinsic viscosity was calculated by the equations.

Relative viscosity $\eta_{rel} = \eta/\eta_s = t/t_s$ 1

Specific viscosity ${}_s\eta_p = \frac{(t-t_s)}{t_s} = \frac{t}{t_s} - 1 = \eta_{rel} - 1$ 2

Reduced Viscosity, $\eta_{red} = \frac{\eta_{sp}}{C}$ 3

Where C is the concentration of PET in the solution.

Intrinsic viscosity was determined by plotting a graph of reduced viscosities η_{red} against concentration, C, and extrapolating the straight line to zero concentration. The intercept on the y-axis is the intrinsic viscosity (Progelhof and Throne, 1993).

TREATMENT OF RESULTS

Melting Point

The melting point for both samples, flakes and reclaimed materials were found to be 256^0 and 254^0C respectively.

Determination of Intrinsic Viscosity

Table 1 and 2 shows the representation of the concentration, time, relative, specific and reduced viscosity of proclaimed and flakes PET respectively. The characterized result for both PET is presented in Table 3.

The viscosity average molecular weight M_v is related to the intrinsic viscosity, η, and was calculated using Mark-Houwink equation.

$$H = KM_v^a \quad \ldots\ldots\ldots\ldots \quad 4$$

Where K and a are constant which are specific for different polymer solute systems at constant temperature. The Mark-Houwink constants for PET dissolved in phenol – 1, 1, 2, 2 – tetrachloroethane are $K = 3.72 \times 10^{-4}$ and a = 0.73 (Brozenick, 1986).

Table 1: Result of Viscosity for Reclaimed PET

Concentration of PET (g/l)	t(sec)	$\eta_{rel} = \frac{t}{t_s}$	$\eta_{sp} = \eta_{rel} - 1$	$\eta_{red} = \eta_{sp/C}$
0.5	85.8	1.41	0.41	0.82
0.25	72.0	1.18	0.18	0.72
0.125	66.4	1.09	0.088	0.70
0.0625	63.7	1.04	0.04	0.64

Table 2: Result of Viscosity for Flake PET

Concentration of PET (g/l)	t(sec)	$\eta_{rel} = \frac{t}{t_s}$	$\eta_{sp} = \eta_{rel} - 1$	$\eta_{red} = \eta_{sp/C}$
0.5	86.2	1.413	0.413	0.83
0.25	72.8	1.193	0.193	0.77
0.125	66.7	1.093	0.093	0.74
0.0625	63.8	1.045	0.045	0.72

Table 3: Result of the Characterization of PET

Characteristic	Flake PET	Reclaimed PET
Intrinsic Viscosity (dl/g)	0.73	0.68
Melting Point (^{0}C)	256	254
Viscosity Average – Molecular Weight (g/gmol)	32.408	9.407

DISCUSSION

The melting point of bottle flake was 256^0C and that of Reclaimed PET was 254^0C, which are quite close to the melting point of commercial product which melt at 256 – 267^0C, while the melting point of virgin fully annealed PET is 280^0C (Drosher and Makrnoid,

1980). The drop in melting point of the reclaimed PET is due to degradation by the thermal energy supplied to melt and homogenize the bottle flakes.

According to Milgrom, 1992; the intrinsic viscosity of one piece bottle blow mould grade PET resins is 0.08 – 0.84dl/g while for two-piece bottle which contain a base cup made usually of high density polyethylene (HDPE) blow mould grade PET resin has intrinsic viscosity of 0.71 – 0.74dl/g. He also stated that when PET is extruded a drop of intrinsic viscosity of about 0.03 takes place. Therefore for this work we assume that the fresh bottles had intrinsic viscosity of 0.8dl/g and 0.72dl/g maximum for the one piece and two pieces respectively which was used in the experiment.

From Table 3 on characterization of PET, the result shows an intrinsic viscosity of 0.73dl/g for the PET flake and 0.68dl/g for the reclaimed PET. The initial drop in intrinsic viscosity to that of PET flake was due to the effect of weathering, oxidation and some other form of degradation which occurred during consumer use. The further drop in intrinsic viscosity was as a result of the homogenization in the reclamation process. Degradation accounted for a drop of about 0.085dl/g while homogenization caused a drop of about 0.05dl/g. The viscosity average molecular weight for PET flake is 32,408 while that of reclaimed PET is 29,407 as shown in Table 3. It was observed that the heat associated with homogenization was responsible for a drop of viscosity average molecular weight of about 3000.

The minimum I. V. requirement for the production of blow mold bottles (one piece) at Up Dike Industries, Owerri is 0.78dl/g and that required for the production of the blow molded two piece beverage bottles at Coca-Cola is 0.71dl/g. The values obtained from this work are close enough and can be reused when upgraded with some percentage of virgin PET. According to Menges, 1995; if recovered single type PET materials have been degraded due to many years of use, the product from such recyclate will be brittle. In order to obtain a high quality product again with such materials about 60 – 70% of virgin PET should be added to get an intrinsic viscosity as the virgin resin. However, modern recycling technology in use today has reduced the amount of degradation due to homogenization by a factor equivalent to an intrinsic viscosity drop of 0.02dl/g. With such development, PET recyclate would have intrinsic viscosity that meets the standard for blow mould grade.

CONCLUSION

This paper shows that PET is an easy recycle thermoplastic polyester as the PET bottle waste stream provides the highest level of purity for feed stock recycling. The work also revealed that environmental factors and weathering have a major effect on and lead to degradation of PET and that heat of homogenization and extrusion contributes to the degradation of PET. Recycled PET finds application in the production of film, fibre and so is economically viable. Further recycling PET help in reducing the amount of non-biodegradable substances in our environment as it also serve as a feed stock to plastic industries.

REFERENCES

Billmyer, F. W. J. (1962). Text Book of Polymer Science. Wiley Interscience, New York p 237.

Bronzenick, N. J. (1986). Modern Plastic Encyclopedia. McGraw-Hill, New York,pp 42 – 46.

Drosher, M. and Makronid, A. (1980). "A Textbook on Chemistry". Doughwart Publishing Company, pp181.789.

Mengers, G. (1995). "Materials Fundamental in Plastics Recycling". Hanser Gardner Publications Inc. pp9, 11, 17 – 20.

Milgrom, J. (1992). "Polyethylene Tetraphthalate (PET)". HAnser Publisher pp47 – 56, 60 – 64.

Progelhot, R. C. and Throne, J. L. (1993). "Polymer Engineering Principles". Hanser Publications Inc. pp82 – 95.

World Resources Foundation (2000). "Journal of Resource Management Plastic"p.2