# ECO-FRIENDLY UTILIZATION OF POLY (ETHYLENE TEREPHTHALATE) "PET" WASTE

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**Abstract**

Poly (ethylene terephthalate) (PET) is a versatile polyester, widely used in large volumes in production of bottles, tapes, food packaging etc. The non-biodegradability and wide-spread application of PET creates huge amount of waste. The increased environmental awareness, legislative measures, and public demand for environmental sustainability are leading to noticeable interest in utilization of PET waste. In paper, the chemical recycling method of PET into bis(2-hydroxyethyl terephthalate) (BHET) using excess ethylene glycol and zinc acetate (trans-esterification catalyst) has been reviewed. The process of utilization of PET waste into high value-added product (urethane oil) has also been described (waste to wealth).

**Key words:** PET (Poly Ethylene Terephthalate), BHET bis(2-hydroxyethyl terephthalate), Ethylene Glycol, Zinc Acetate and Urethane Oil.

## I. INTRODUCTION

PET Poly (ethylene terephthalate) is important thermoplastic polyester. By virtue of excellent tensile and impact strength, chemical resistance, clarity, process ability and reasonable thermal stability [1], it is used in large volumes in production of fibers, bottles, tapes, films and food packaging [2]. The synthetic polymer do not degrade easily, thus the extensive use and non-biodegradability of PET generates huge amount waste [3]. The effective utilization of PET waste has therefore received wide attention due to concern of environmental protection, preservation of resources and economic benefits.

## II. DIFFERENT METHODS OF WASTE PET UTILIZATION

The methods of managing plastic waste are land filling, composting, incineration, recycling, and sewage.

However recycling is the most economic method because

(i) it prevents plastic litter

(ii) it reduces the exploitation of non-renewable petroleum i.e. plastic raw material [preservation of resources].

(iii) limits the quantity of plastics sent to landfills

(iv) provides cheaper route to plastic production,

(v) and above all, is a revenue earner [1].

## III. RECYCLING METHODS

The two global methods for recycling of PET waste are mechanical and chemical methods [2, 13].

According to the Environmental Protection Agency (EPA) "recycling" is considered to be processing of waste to make new article.

Recycling has three distinct approaches [4]:

1 it could be reused directly;

2 it could undergo physical reprocessing, i.e. mechanical method. For example, grinding, melting and reforming;

3 it could undergo chemical treatment.

Chemical recycling processes for PET are divided as follows [5,14]: (i) glycolysis,

(ii) methanolysis,

(iii) hydrolysis (alkaline, acidic and neutral) and,

(iv) other processes such as aminolysis or ammonolysis

The chemical recycling process is the process leading to total depolymerization of PET into monomers, or partial depolymerization into oligomers and the other chemical substances [1].

## IV. GLYCOLYSIS PROCESS

Glycolysis is the commercially accepted process as it makes possible to employ very low amounts of reactants, as well as applying lower temperatures and pressures, in contrast with other methods [1]. In case of hydrolysis, it causes corrosion and pollution problems [6].

Glycolysis can be described as a molecular depolymerisation process by transesterification between PET ester groups and a diol, usually ethylene glycol (EG) in excess, to obtain the monomer bis(2-hydroxyethyl terephthalate) (BHET), in this process ester linkages are broken and replaced with hydroxyl terminals [5].

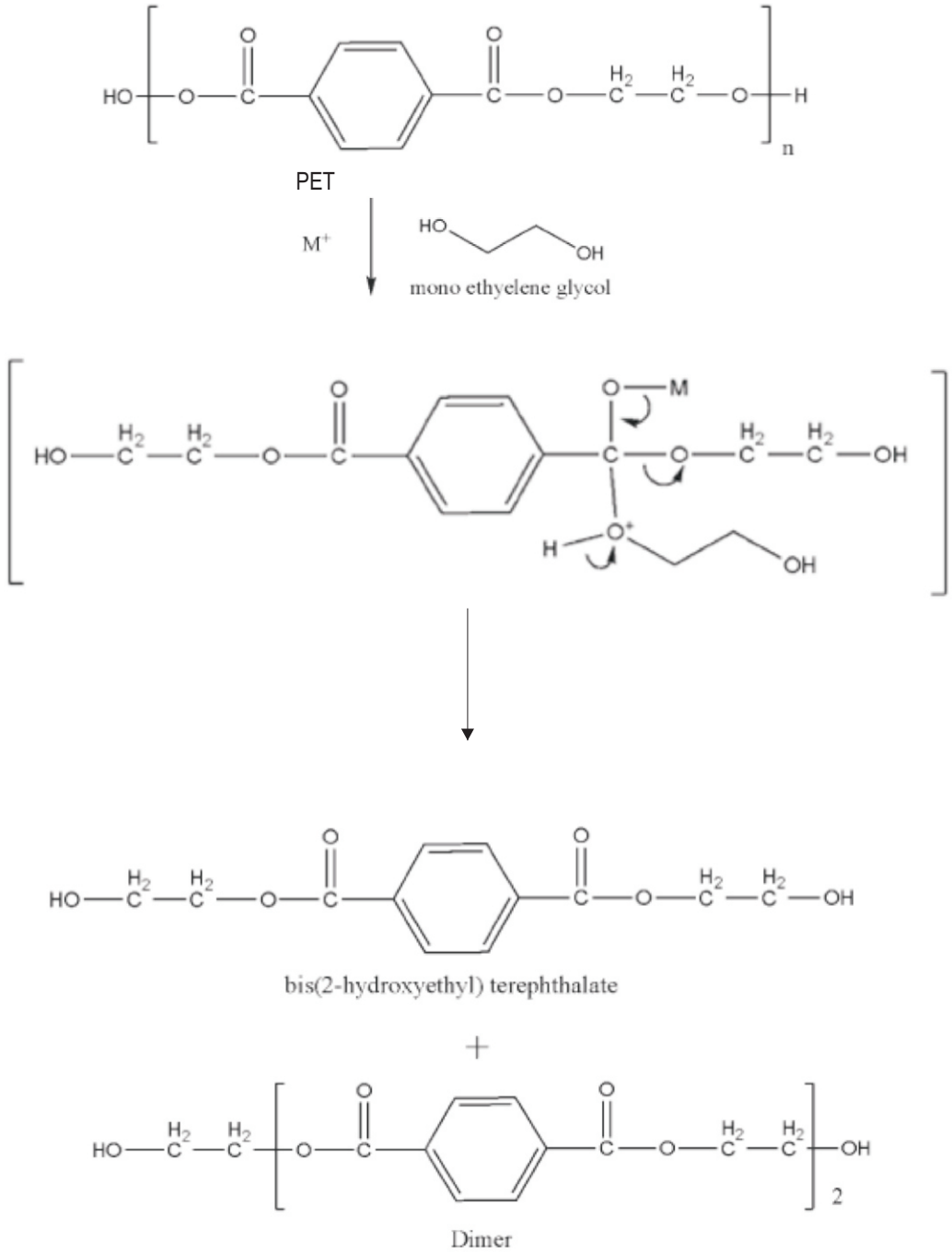



Fig.1. Mechanism of glycolytic depolymerization of PET.

Various polyols are used for the process but EG found out to be the best with PET: EG ratio 1:4 [8]. The process is carried out without catalyst at 220$^0$C and with catalyst at 190-196$^0$C [11]. Different catalysts are being used for the process such as metal acetates, metal halides, zeolites etc. Metal acetate – zinc acetate found to be the most effective. The transesterification catalyst – zinc acetate is used in concentration of 0.25-0.5% of PET [9, 12, 15]. Recently, ionic liquids have been reported as the catalyst for PET glycolysis [32, 33].

The depolymerisation product obtained is a mixture of BHET (monomer) and oligomers. BHET can be polymerized after purification to produce PET [14].

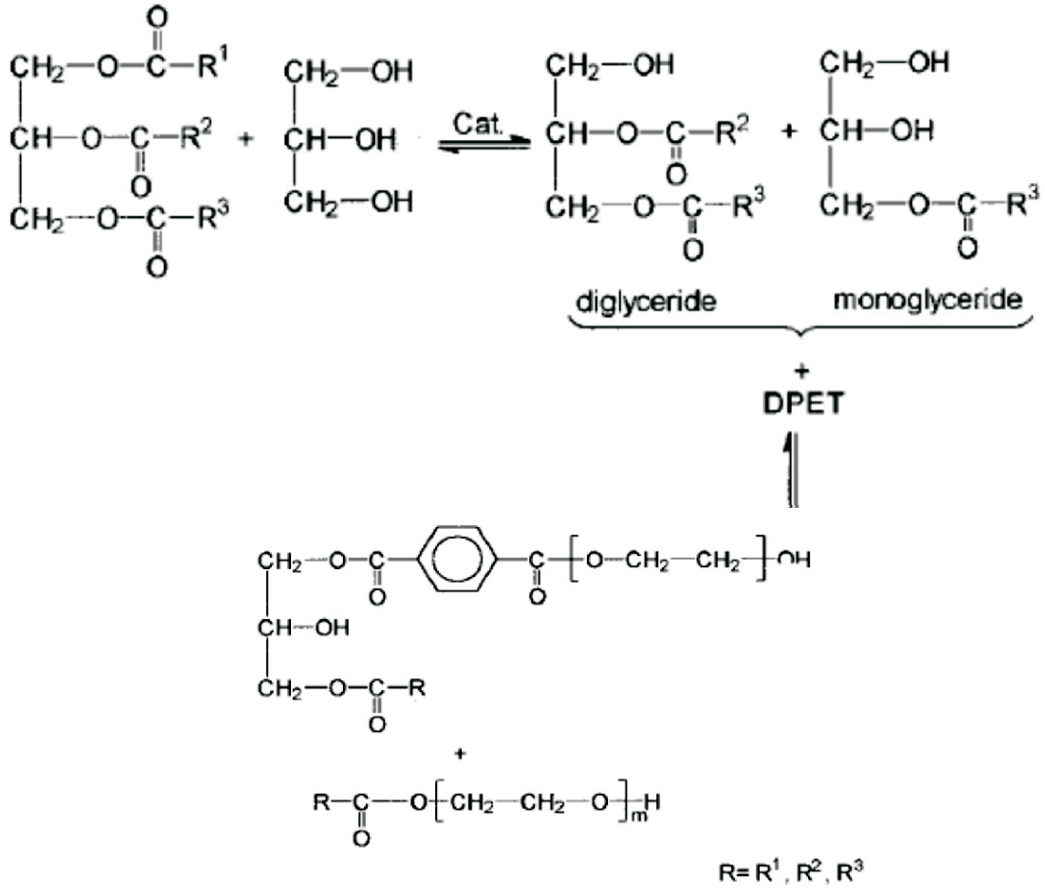
The depolymerised product can be directly utilized for synthesis of high value added products such as urethane oil (varnish).

Synthesis of Urethane Oil: The synthesis of urethane oil from PET waste could be achieved in 3 steps:

**Scheme 1:** Glycolysis of PET as showed in Fig 1.

**Scheme 2:** Depolymerized PET is mixed with glycolyzed glyceride oil and heated to about 230$^0$C in order to achieve the transesterification reaction (Fig. 2).

A mixture of monoglyceride and diglyceride is produced by glycolysis of glyceride oil with glycerin. The ratio of monoglyceride to diglyceride is regulated by the mole ratio of glyceride oil and glycerin which is about 2.5 to produce a higher amount of diglyceride.




$R_1, R_2, R_3$ : Alky groups of fatty acids of soya bean oil.

Fig. 2. Transesterification of depolymerized PET with mono/diglyceride of oils

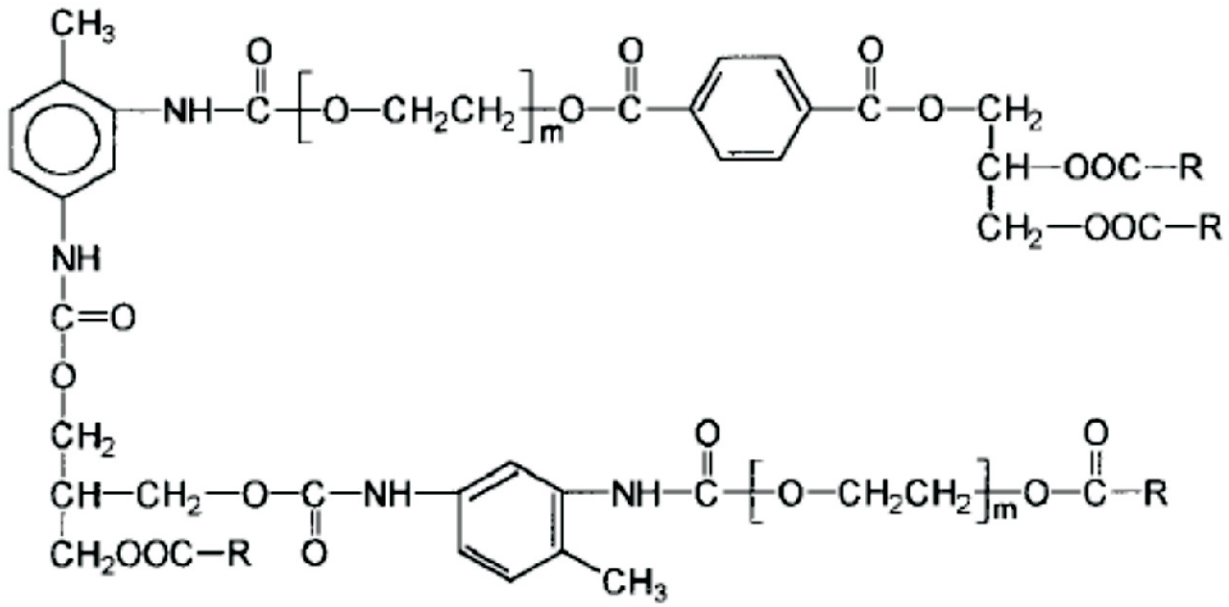


Fig. 3. Structure of Urethane oil.

**Scheme 3:** The product of the transesterification reaction (shown in Fig. 2) is mainly a mixture of five different hydroxyl containing compounds. They are glycerin, monoglycerides, diglycerides, fatty esters of diols, and mixed esters of fatty acids with depolymerized PET. This mixture is reacted with TDI to produce a new kind of urethane oil (Fig. 3) [10].

The process of recycling and depolymerization of PET is an effective route for alleviation of PET waste and can be conducted under different chemical conditions [16-22]. PET was reported also to be depolymerized under the effect of microwave radiation [21, 22] and using sub and supercritical fluids [31].

The depolymerized product obtained from glycolysis of PET finds its use in various other applications such as synthesis of plasticizers [23], unsaturated polyester resins [24], methacrylated oligoesters [25, 28], Alkyd resins [29] textile dyes, and softeners etc [26, 27].

Recently, a very interesting application of glycolyzed PET is reported. The depolymerized product is used for production of polymeric inorganic composite i.e. unsaturated polyester Ce(IV) phosphate and this polymeric inorganic composite can act as a cation exchanger for the removal of malachite green dye from water samples [30].

## V. CONCLUSION

PET waste is depolymerized by glycolysis to produce low molecular weight hydroxyl-terminated oligomers which are converted into urethane oils with physical properties comparable to commercial products.

The method described is important in terms of utilization of waste PET, and the price of the varnishes produced with this method may be comparably lower than those of commercial ones.

The process described in the paper is solvent-free, catalytic glycolysis process, with no use of any hazardous chemicals, and waste is converted into useful product (wealth). Hence the process is greener and environment-friendly.

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