# CHAPTER I

# INTRODUCTION

## 1.1 High Density Polyethylene

High Density Polyethylene (HDPE) is a thermoplastic polyolefin manufactured by ethylene polymerization with density 0.940 g/cm.$^3$ or higher. Linear HDPE was first prepared from diazomethane in the early 1950's. HDPE is manufactured by either Phillips process or Ziegler-Natta process.

HDPE is used for many packing applications because it provides excellent moisture barrier properties, good chemical resistance and good stiffness. The growth of HDPE has been attributed to a combination of factors, including a set of physical properties which has resulted in strong market acceptance of molded and extruded products. Major physical properties which have been market assets are :

- Good chemical resistance to most household chemicals
- Good moisture and water vapor resistance
- Good dielectric properties
- Recyclability

HDPE is one of several commodity plastics which are used for packaging applications. Among the variety plastic packaging materials, polyethylene is the dominant thermoplastic resin in packaging's major market. In 1993, rigid bottles, jars, food containers, buckets and shipping containers and the various application of flexible packaging accounted for 34.4 % of total thermoplastic resin usage. As seen in figure 1.1 showing the packaging

market in 1994, 65.4 % of the thermoplastic resin used in packaging was polyethylene. HDPE shared 30 % of the thermoplastic materials used for packaging application which was the highest portion in the packaging market. [Zahavich, 1995]

**Packaging Market 1994**

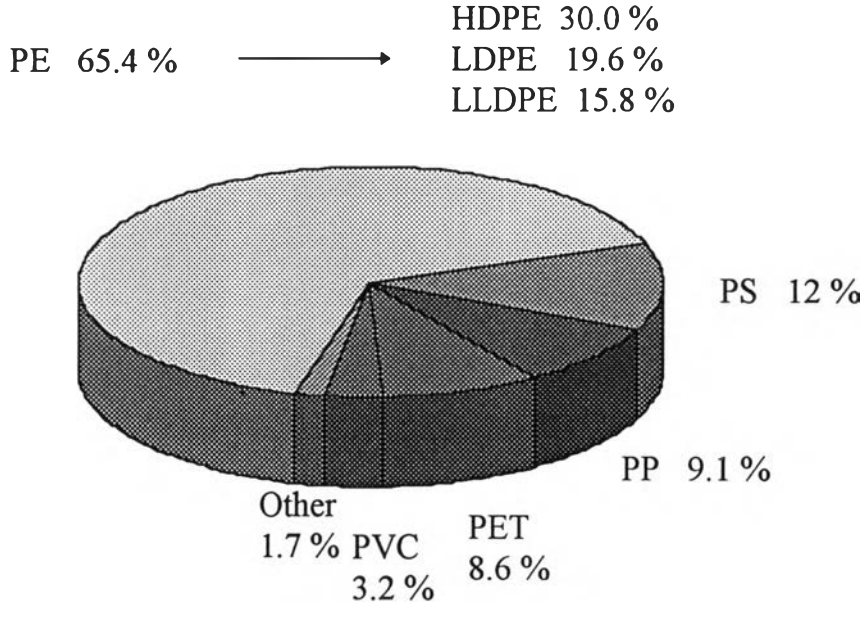


**Figure 1.1** The plastic packaging market in 1994.

Blow molding is one of the major driving forces behind the market growth for HDPE. The backbone of this market growth is gains in HDPE bottle demand for liquid foods (milk, juices, water, etc.) as well as bottles for household chemicals. [Unterreiner, 1995] Consequently HDPE container are one of the major sources of solid waste causing environmental pollution. Recycling offers a significant opportunity to reduce the amount of plastic in the solid waste stream and preserve the environment.

## 1.2 Recycling of High Density Polyethylene

Recycling has become the main response to the environmental challenge facing plastics producers, processors and end-users. Recycling is generally taken to refer to primary and secondary recycling. Primary recycling transforms a product into a product similar or identical to the original. This is generally regarded as the purest form of recycling. Secondary recycling is the processing of waste into a product with less demanding physical and chemical properties. Processing of industrial plastic scrap has taken place for many years but recycling of post-consumerplastic waste was virtually non-existent 10 years ago, PET and HDPE continued to be the most recycled products. [Johnson, 1993] The American Plastic Council (APC) announced that plastic bottle recycling grew 21 % in 1994 over the previous year and recycling of two large volume plastic packages-soft drink and milk bottles - continued strong growth during 1994. The recycling rate for PET soft drink bottles topped 48 %, compared with 41 % in 1993; the recycling rate for natural HDPE bottles reached almost 26 %, compared with 24 % in 1993. [Cavaney, 1995]

Today HDPE plastic bottle recycling has become more attractive due to several factors. These include :

1. large quantities of HDPE scrap have become available as a consequence of more municipal waste recycling programs,
2. the bottles are of single material composition and
3. HDPE is a material that is relatively easy to reprocess.

HDPE bottles can be recycled into other bottles, flower pots, large rigid containers, plastic lumber and heavy duty film. Technological advances are increasing the potential for the displacement of virgin resin. The

recycled resin prices are even more difficult to benchmark then that of virgin resin. Post-industrial resin prices have always been lower than post-consumer resin. At present, both types of recycled resin are less expensive than virgin resin. [Black, 1996]

Recycled resin prices

| HDPE (clean) | pellets | flake |
|---|---|---|
| | c / lb. | c / lb. |
| Natural post-consumer | 24 - 34 | 18 |
| Green post-consumer | 20 - 30 | 14 |

Lever Europe estimated that they will be using 5000 tons per year of recycled HDPE by using 25 % post-consumer resin in their detergent bottles. Proctor and Gamble and Owens Brockway in the US have introduced a colored HDPE bottle for fabric softener made out of 100 % recycled HDPE from post-consumer sources. In 1992, Blueberry Plastic began recycling HDPE milk containers and LLDPE film with the intention of using 100 % recycled resin in beverage bottles. [Johnson, 1993]

## 1.3 Literature Review

This work was concerned with the reprocessing of HDPE in an extruder and the effects of post-consumer HDPE or regrind on the properties. Thermal-mechanical degradation and the reactions occurring during processing such as chain scission, chain branching and crosslinking are typically involved.

Hinsken et al. ( 1991 ) studied the degradation of polyolefins during melt processing. They evaluated change in molecular weight, melt flow index (MFI), viscosity and molecular weight distribution (MWD) of HDPE during reprocessing for 5 passes. They found that HDPE showed a tendency towards crosslinking as a result of increasing molecular weight.

Acierno and Maio (1995) studied the processability of a waste HDPE-LDPE system by using multiple extrusion tests to verify in which way working conditions may influence flow and mechanical characteristics of the system. They pointed out that the rheological properties did not change too much while mechanical tests revealed a presumed marginal degradation of the polymer after three extrusion.

Ram and Getz (1984) explored ways for the improve flow and product performance of reclaimed LDPE by intensive shear processing. After repetitive processing cycles of injection molding extrusion or roll milling, there was an increase in MFI, decrease in elasticity and increase in the elongation at break for the recycled LDPE. Under the same conditions virgin LDPE demonstrated an opposite response to intensive shear. The MFI dropped while elongation was essentially not affected.

Doyan et al. (1994) studied the processability and the mechanical properties of closed-loop extruded HDPE. They showed that the molecular weight obtained from intrinsic viscosity and crystallinity was higher after 10 cycles than that after 1 cycle. Also they concluded that both chain scission and crosslinking occurred simultaneously during extrusion. Chain scission was the dominant factor for the first cycle and crosslinking took over after a while because of the accumulation of free radicals during extrusion.

Pattanakul et al. (1991) investigated the effect of virgin HDPE/ recycled HDPE from milk bottles composition on the mechanical and physical changes. They indicated that no change in the flow properties occurred and no effect of composition on tensile strength was seen. In addition, they suggested that the recycled HDPE from milk bottles was a material with useful properties not largely different from those of the virgin material. Bogardus (1995) examined the use of regrind and its effects on the mechanical properties of a part coming off the extrusion line. They used HDPE mixed with different percentages of regrind ranging from virgin to 100 % regrind. He pointed out that HDPE was a very stable material with the addition of regrind having only a small effect. All of the mechanical properties at break decreased with the addition of the regrind due to the breakdown of the molecular chains.

## 1.4 Objectives

1 ) To study the influence of reprocessing on processability, rheology, thermal properties and mechanical properties of virgin/ post-consumer HDPE blends at various ratios.

2 ) To study the effects of the amount of post-consumer HDPE from water bottles on those properties.

## 1.5 Statement of Problems

1) How do the number of passes affect the properties of virgin/ post-consumer HDPE ?
2) After which number of passes do the properties drop ?
3) How does the amount of post-consumer HDPE affect properties ?