CHAPTER I

INTRODUCTION

1.1 Background

A major reason for recycling materials is to ease today's solid waste management and disposal problem which is of global concern. Recycling reduces the municipal solid waste stream, which is the amount of waste collected from residential, commercial, institutional, and selected industrial sources. In the past, all solid waste materials ended up as landfill. Another important reason for recycling materials is to reduce the dependency on natural raw materials, especially non-renewable raw materials such as oil and natural gas.

Recycling is still new to the plastic industry because of the present abundance of raw material resources. In the future, the available resources will decrease and the demand for such dwindling resources will inevitably result in an increase in prices. So, the raw materials situation in combination with environmental solid waste management has forced both governments and industry to seriously consider plastics recycling. It is also clear that society is becoming more and more committed to the concept of resource conservation and environmental preservation. Obviously, recycling is one of the most efficient ways to achieve these goals.

Plastic recycling means the recovery of any used items that have been diverted from disposal and the diverted materials could be either pre-consumer or post-consumer in nature. Recycling is also conducted in the interests of public health. It has been reported (Cornell, 1995) that the recycling of used plastic bottles in the U.S grew from 363 millions pounds in 1990 to 891 million pounds in 1993, an annual growth rate of 35%.

Polymers such as high-density polyethylene (HDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), and polypropylene (PP) are used for making rigid containers or blow molded bottles. The first post-consumer recycling of a generic polymer was PET (Rader *et al.*, 1995).

Printing ink on plastic surfaces is essential in the packaging industry as the printed plastic is aesthetically pleasing, colorful and attractive for the customer when making a purchasing decision. But the ink must not change the properties of the plastic material and must not affect the contents of the package.

During plastic recycling, residual ink can color the polymer and cause it to be less stiff, weaker and denser than the original plastic (Gecol, 1998). These problems can be avoided if the ink is removed from the polymer surface before recycling. Two methods which can be use for deinking of plastic products are by treatment with either organic solvents (e.g., acetone) or surfactants. The use of surfactants to deink (remove the ink) from the polymer surface involves green chemistry because surfactants are not generally environmentally harmful. Deinking using surfactants is an example of surfactant-based separation processes (Scamehorn and Harwell, 1989; Scamehorn and Harwell, In press).

Ink can be defined as a dispersion of pigments or dyes in a fluid carrier (vehicle). There are two types of inks available for the printing of commercial plastic packaging materials: ultraviolet curing printing inks and conventional inks. Conventional inks are used for both the screen and pad printing processes to print rigid plastic containers such as blow molded bottles while the UV curable inks are usually used for printing on plastic closures (caps, lids, etc.).

Conventional printing inks are composed of pigments, binders, carriers, and additives. Organic and inorganic pigments give color and opacity to the ink and influence its fluidity. Binders, which are mostly low molecular weight polymeric resins disperse the pigments and retain them on the plastic surface after printing. The carrier is a liquid which provides fluidity for the ink and transfers the ink from the printing system to the plastic substrate. After application, the carrier should evaporate quickly and completely. Additives in the ink include waxes, surfactants, drying agents, and antioxidizing agents.

Conventional printing inks are classified as either solvent-based or water-based depending on the type of carrier. The carriers for solvent-based inks are solvents, solvent mixtures or water miscible solvents whereas water-based inks use water as the carrier, which could contain up to 20% alcohol (Gecol, 1998).

It is essential that the ink wets the surface of the plastic to produce a uniform covering and to bond strongly to the surface during printing. There are a number of treatment processes used for plastic surfaces in order to increase the surface energy of the plastic and thereby enhance the wetability of the ink. These processes are chemical treatment, flame treatment, corona discharge, plasma treatment and ultraviolet treatment. Flame treatment is the most common process used to improve ink adhesion to molded polymer articles such as rigid plastic containers.

It is believed that flame treatment oxidizes the surface of the plastic and makes it more easily wettable. Flames contain exited species of O, NO, OH, and NH, which can remove hydrogen from the substrate surface; the oxidation that follows is thought to propagate by a free radical mechanism.

The plastic surface is contacted for a period of less than 1 second with the oxidizing portion of the flame. The gas is burned using 10-15% excess air over the stoichiometric ratio in order to obtain an oxidizing flame with a temperature of 1090 – 2760°C (Satas, 1986).

1.2 Problem Statement

A pressing and burgeoning problem both in the United States and internationally is the difficulty of disposing solid waste, including plastic. The ability to recycle plastics more economically would decrease solid waste disposal throughout the world and reduce the petroleum demands required to make polymer feedstocks.

Due to the increasing demand for plastic film packaging materials and the need to remove printing ink from the films for effective recycling, a research program has been carried out by a collaborative research group in the United States between the University of Oklahoma, the University of Tulsa, Kimberly-Clark Corporation, and other companies for developing improved methods of ink removal from plastic films to permit recycling of the polymer.

The research program, approved by the National Science Foundation in the United States, employs a two-fold approach for solving the problem of deinking plastics films. Firstly, to determine the optimum conditions for utilizing aqueous surfactant solutions to remove inks, principally those of the widely-used flexographic type, from polymer surfaces and secondly, to develop modified inks that will maintain the required print quality and durability and be much easier to remove from plastic films than conventional inks (NSF research proposal no. 9720161, 1997).

Some tests have already been done on the de-inking of plastic films using different types of surfactants and the results were very promising

(Gecol, 1998). In a related research topic (Gecol, 1998), it was shown that deinking with surfactant solutions is more effective than de-inking with surfactant-free solution. The removal of water-based and solvent-based inks from plastic films by using different types of surfactant at different pH levels was studied in that research and the effectiveness of de-inking by the cationic and anionic surfactants was compared.

Although different aspects of de-inking of plastic films by using surfactants were studied in that research, it would be very useful if one could further determine the optimum process parameters and levels to improve the effectiveness of de-inking of screen printed rigid containers or blow molded bottles. By doing so, it should be possible to accurately determine and set the process parameters which are most influential on the effectiveness of de-inking. As a result, we could improve the process yields in terms of higher quality de-inked plastic products.

Deinking is fundamentally a laundering process. The adhesion of ink to plastic packaging materials and soil to clothing is due to van der Waals, electrical and mechanical forces. Like laundering, deinking is a two steps process: (i) detachment of soil (ink) from the substrate (plastic packaging) by a chemical mechanism and (ii) separation of soil from the substrate and dispersion of soil in a washing bath by mechanical action (Borchardt, 1994). The effect of surface tension, surfactant adsorption, wetting, dispersion and solubilization are important in the deinking process. It is well known that liquids wet substrates that have higher critical surface tension values than the liquid surface tension. During printing, the lower surface tension effect causes the ink to wet the polymer surface very well and apparently adhere to the surface better (Ellis and Teeters, 1997). The removal of ink from polymer surfaces with the use of surfactants is aided by adsorption of surfactants onto the polymer and ink surfaces, thereby decreasing the interfacial tension values of both polymer-water and ink-water. If the reduction of interfacial tension is so strong that the sum of the interfacial tensions of ink-water and polymer-water is equal to or less than the ink-polymer interfacial tension, it is thermodynamically favorable for the ink to detach from the polymer surface. Convective currents and rubbing of the polymer surface against another solid (e.g., other polymer or abrasive) aid in detachment (Gecol, 1998). Convective currents from agitation or shaking help keep the detached ink dispersed (Lange, 1994), aiding in antiredeposition. In this research, the removal of screen-type solvent-based ink printed on flame-treated HDPE blow molded bottles was studied using different surfactants with and without abrasive materials. Cationic, anionic and nonionic surfactants are widely used in detergent formulations, paper deinking, and textile washing processes (Lange, 1994; Borchardt, 1993; Jacobi and Lohr, 1987). Solvent-based ink is widely used because the printing generally is of higher quality than water-based ink. In a previous study of deinking of polyethylene film (Gecol, 1998), solvent-based inks were found to be much more difficult to remove than water-based inks.

1.3 Objectives of the Study

The main objectives of this research project are:

1. To study the removal of solvent-based ink from rigid plastic surfaces in order to produce ink free surfaces

2. To study the effectiveness of de-inking from rigid plastic surfaces under a variety of conditions such as type of surfactant, pH range, temperature, surfactant concentration, and abrasive material.

1.4 Scope of Research Work

The following surfactants were studied at various pH levels:

(a) cationic hexadecyltrimethylammonium bromide **(CTAB)**

(b) anionic sodium dodecylsulphate **(SDS)**, and

(c) nonionic polydisperse nonylphenol polyethoxylate **($NP(EO)_{10}$)**.

The surfactants will be studied for their effectiveness in removing solvent-based inks from rigid plastic surfaces under a variety of conditions. Only screen-type solvent-based ink used to print commercial HDPE blow molded bottles will be used for the deinking experiments to get higher quality ink-free recycled products.