



CHAPTER I INTRODUCTION

One of the most interesting aspects in the detergency mechanisms are how particulate soils to be removed from fabric surfaces. Studies of detergency have emphasized on formulation development. Laundry detergency can be defined as the removal of unwanted substances (soils) from fabrics with an aid of surfactant. Laundry detergency is a complicated process which depends on several factors such as nature and concentration of washing solutions, additives (builders, enzymes, antiredeposition agents), nature of solid surfaces, hydrodynamic conditions, mechanical action during washing, water hardness, temperature, and electrolyte concentration (Azemar, 1997). Soil can be classified into four groups: oily soil (usually organic liquid), particulate soil (inorganic solid), solid non-particulate soil (waxy solids like solidified hamburger grease), and stain formation at a chemical bond between soil and fabric (e.g., wine, blood) (Lance, 1994; Kissa and Cutler, 1987; Carroll, 1995). Particulate and solid non-particulate soil removal studies have largely been empirical, in part because fundamental parameters such as soil/solution interfacial tensions are difficult or impossible to be measured and correlated to soil removal efficiency. Particulate soils are solid particles deposited mostly from air suspension. Examples of such dust include carbon black, clay, alumina, silica, iron and other metal oxides. These particulates usually have a large specific surface area, so oil and greases can co-adsorb very readily, resulting in mixed soils. Particulate soils are difficult to be removed because of their rigidification and water insolubility. Moreover, they can redeposit on surfaces that have been cleaned (Lance, 1994).

There are several mechanisms, which can be important in particulate soil removal in laundry detergency (Azemar, 1997). When adsorbed particles are detached from the fabric surface, two new interfaces are created (soil/bath and textile/bath) while only one interface is destroyed (soil/textile). The soil detachment is thermodynamically favorable when the sum of the interfacial tensions (IFT) of the two new surfaces is lower than the interfacial tension of the destroyed surface (Grindstaff *et al.*, 1967). This effect can be quantified by the work required for the

particulate soil removal (W) as described by Equation 1, which must be negative in order to favor soil removal.

$$W = [\gamma_{SB} + \gamma_{TB}] - \gamma_{ST} \quad [1]$$

where γ_{SB} = interfacial tension at soil/bath interface,
 γ_{TB} = interfacial tension at textile/bath interface,
 and γ_{ST} = interfacial tension at soil/textile interface

Adsorption of surfactant onto the soil and onto the fabric from the bath can reduce these solid/solution interfacial tensions, increasing the thermodynamic favorability of detachment (Schwartz, 1972). The electrical potential of the soil and fabric can be affected by surfactant adsorption, leading to the enhancement of soil detachment. Electrostatic and steric stabilization of dispersed soil particles following detachment are important for antiredeposition mechanisms and can be affected by surfactant adsorption. A theory for particle removal from the fabric surface, based on the DLVO theory of colloidal stability, was developed by Lange (1967). Zeta potential is generally used as a representative of electrostatic repulsion force. This has led to attempts to correlate soil removal with the zeta potential of the fibers and soils in a washing liquid. Since most textile fibers and soil particles are negatively charged in aqueous solutions, the magnitudes of the charges of both surfaces are further increased by the adsorption of anionic surfactants (Schott, 1972). The repulsive forces between the similar charges of fiber and soil contribute to the detachment of soil (Goette, 1949) and also prevent soil redeposition (Kling and Lange, 1959). The correlation between the zeta potentials and the particulate soil detergency was also observed by Harris (Harris, 1958). In contrast to anionic surfactants, cationic surfactants can cause a decrease in washing effectiveness and even below that with pure water. Significant soil removal only occurs only at high surfactant concentrations, at which a complete charge reversal takes place on both surface of fabric and soil (Jakobi and Lohr, 1987).

Wetting of fabric or soil by the bath can affect detergency since imbibitions of the bath solution into the fabric weave is required for contact between the textile surface and the surfactant solution and to permit the subsequential detachment/dispersing of particulate soil. The contact angle between bath and either

fabric or particle surface (wettability) along with bath/air surface tension values can be used to calculate solid/bath spreading pressures which are closely related to solid/bath interfacial tensions (which can't be easily measured if at all). Cotton can be used as a model hydrophilic fabric, while polyester represents a model hydrophobic fabric. The polyester fibers are smooth cylinders while the cotton has substantial fraying or small fibers sticking out from the large fibers, leading to the possibility of entrapment of soil particulates in this mass of small fibers. The importance of this particle filtering can be illuminated from scanning electron micrograph (SEM) images. The relationship between the particle size of carbon black and its adhesiveness to cotton were first studied by Compton and Hart (1953). Later, Grindstaff et al. (1967) reported that the carbon black could be more easily removed from the polyester fabric than that from the cotton fabric because of the physical entrapment of the particles by the cotton fabric. The SEM images can show the configuration of particles on fabrics. Particulate soils are the agglomeration of small particles and most of these microparticles are not in direct contact with the fabrics at all. Hence, two actions may occur during washing process; removing the whole agglomerate by breaking the bond between the fabric and the contacting soil particles, or the particle agglomerate may be dispersed, causing removal of most of the soil with some particles still remaining on the fabric (Schwartz, 1972). Besides the detachment of soil particles from fabric, the detached particles have a tendency to go back onto the substrate (redeposition). A more homodisperse distribution of particle sizes should reduce redeposition (Schwartz, 1972).

In this research, the removal mechanisms of carbon black (model hydrophobic soil), ferric oxide and kaolinite (model hydrophilic soils) from cotton (hydrophilic substrate) and polyester (hydrophobic substrate) were investigated by using five surfactants: three anionic surfactants, (sodium dodecyl sulfate (SDS), methyl ester sulfonate (MES), and linear alkyl benzene sulfonate (LAS)), a nonionic surfactant (octylphenol ethoxylate (OP(EO)10)) and a cationic surfactant (cetyltrimethyl ammonium bromide (CTAB)). The zeta potential, solid/liquid spreading pressure, contact angle and surfactant adsorption of both soil and fabric were correlated to detergency and antiredeposition performance over a range of surfactant concentration and different pH levels. For the first part of this work, the

mechanistic studies of hydrophobic soil removal (carbon black) were carried out using different types of surfactants and solution pHs as describe in Chapter IV. The mechanistic studies of hydrophilic soil removal (ferric oxide and kaolinite) by followed the similar surfactants as part I was described in Chapter V. For Chapter VI, the performance of methyl ester sulfonate (MES) for both hydrophobic soil (carbon black) and hydrophilic soils (ferric oxide and kaolinite) removals was investigated. Furthermore, the overall conclusions and recommendations are given in Chapter VII.