



## CHAPTER II

### BACKGROUND AND LITERATURE REVIEW

#### 2.1 Microemulsions

Microemulsions are thermodynamically stable system consisting of water, oil and surfactant and microemulsions are transparent dispersion containing two immiscible liquids with particles of 10-100 nm (0.01-0.1  $\mu\text{m}$ ) in diameters that are generally obtained upon mixing gently of oil and water in the presence of surfactants. The microemulsion “phase” is that which contains most of the surfactant or surfactant “rich” phase. The first report of the characteristics of microemulsion was in 1940 (Schulman and Cockbain, 1940), which are the ultralow interfacial tension between water and oil phases, high solubilities of both oil and water and spontaneous formation.

Microemulsions can be divided in two cases (Rosen, 2004). For the first case, a first liquid is completely solubilized in a second liquid to have a single phase. There has no interface against either liquid as the micelles are capable of solubilizing completely the first liquid. For the second case, a dispersion of the tiny droplets of a first liquid in a second liquid, and the interfacial tension of the microemulsion against both these liquids must be close to zero. The interfacial area is so large that an exceedingly low interfacial tension must be present to permit formation at the microemulsion with so little work. However, the types of microemulsions can be normally classified as the Winsor Type microemulsions as following.

##### 2.1.1 Types of Microemulsions

Most studies of phase equilibrium of microemulsions are probably known as the Winsor Type microemulsions (Winsor, 1954). There are four types of microemulsions as follows;

1. Winsor Type I microemulsion: There are two equilibrium phases which are an oil-in-water microemulsion phase and an excess oil phase. It can be called an oil-in-water microemulsion because oil droplets disperse in the water phase.

2. Winsor Type II microemulsion: There are two equilibrium phases which are a water-in-oil microemulsion and an excess water phase. It can be called water-in-oil microemulsion because water droplets disperse in the oil phase.

3. Winsor Type III microemulsion: The three phases consists of non-droplet type microemulsion (bicontinuous phase), an excess water phase and excess oil phase. The equilibrium bicontinuous microemulsion phase, locates between the excess oil and excess water phases. Hence, the Winsor Type III microemulsion is known as the middle phase microemulsion.

4. Winsor Type IV Microemulsion: The single phase of microemulsion appears at a very high surfactant concentration.

Normally, the phase transformation from Winsor Type I to Winsor Type III to Winsor Type II can be achieved by progressively changing temperature, salinity, the molecular structure of surfactant and cosurfactant, oil-to-water ratio, or the structure of oil in a homologous series. With changing the type of microemulsion, the interfacial tension (IFT) of the system is changed and it can be roughly classified the type of microemulsion beyond visual observation. The typical relationship between the type of microemulsion and the IFT is shown in Figure 2.1. Studies of microemulsion formation are done by varying salinity of the system while holding other variables constant which is known as salinity scan (Bourrel and Schechter, 1988). The region on the left hand side of this figure is a Winsor Type I microemulsion or oil-in-water microemulsion (o/w) equilibrating with an excess oil phase. The IFT between the excess oil phase and the micellar solution ( $\gamma_{o/m}$ ) decreases with increasing salinity. When the middle phase is formed, the microemulsion phase becomes bicontinuous structure in equilibrium with excess oil and excess water phases. The point in the middle phase microemulsion region, where the IFT between the excess water and the middle phase ( $\gamma_{w/m}$ ) equal to the IFT between the excess oil and the middle phase ( $\gamma_{o/m}$ ) is known as the minimum IFT of the system or the optimum point that is shown as the optimum salinity. If the system HLB (hydrophilic-lipophilic balance) is further decreased, a Winsor Type II microemulsion transforms to a Winsor Type III microemulsion as shown on the right



swollen due to the high solubilization of oil. Eventhough the IFT in the supersolubilization region is not as low as that at the optimum condition in the Winsor Type III microemulsion region; the supersolubilization region still provides considerably high solubilization but not ultralow IFT without formation of middle phase. At the optimum condition in the phase diagram, the solubilization parameter is referred as  $SP^*$ . With the lowest IFT at  $S^*$ , the highest solubilization parameter is expected to be obtained as described by the Chun-Huh relationship. According to the Chun-Huh relationship (see equation 2.1), the solubilization capacity increases as decreasing IFT.

$$SP^2 = \frac{C}{IFT} \quad (2.1)$$

These unique properties of microemulsion in terms of ultralow IFT and high solubilization are very useful for many industrial applications. It is believed that the ultrlow IFT and high solubilization of Winsor Type III microemulsions can improve detergency performance in laundering process.

## 2.2 Application of Microemulsion for Detergency

The relationship between the microemulsion formation and detergency has been established for decades (Dillan *et al.*, 1980; Carroll, 1996). High efficiency of soil removal from fabrics was found in the presence of the microemulsion of water/tetraethyleneglycol dodecylether/hexadecane even in the conditions of minimum mechanical energy and at low temperatures. In addition, it was found experimentally that a higher washing efficiency of the microemulsion-based system was observed in a comparison with 1% commercial liquid detergent aqueous solution. Furthermore, an addition of a small amount of sodium tripolyphosphate or sodium citrate as a builder in the microemulsion-based formulation was found to enhance considerably the efficiency of oily soil removal (Solans *et al.*, 1985). The study of microemulsion application for detergency and relationship between IFT and detergency was investigated (Dörfler *et al.*, 1996). The maximum detergency of the microemulsion-based systems in this work, using decane as a model of oily soil, was

found to correspond to a minimum value of the IFT of  $10^{-3}$  mN/m. In addition, the detergency performance between the microemulsion-based formulation of C<sub>12-14</sub> alkylpolyglycol ether/n-pentanol was tested as compared to a standard detergent solution. The results showed that the oil removal obtained from the microemulsion-based formulation which exhibited ultralow IFT and maximum solubilizing power was clearly greater than that using the standard detergent. In addition, the similar results were also reported that the maximum detergency correlated to the minimum IFT (Azemar, 1996; Goel, 2000).

However, this concept was challenged by Thomson; a sharp maximum detergency which did not quite coincide with the minimum IFT was reported and therefore did not entirely confirm the correspondence of maximum detergency and minimum IFT. Double maximum detergency peaks were observed; one of them corresponded to the minimum IFT which presented in the Winsor Type III microemulsion region, whereas the second maximum detergency was believed to attribute to the roll-up mechanism based on the concept of cohesive and adhesive works between oil and fabric substrate (Thompson, 1994).

Garti *et al.*, (2001) investigated the effect of adding other composition (such as cosurfactant and alcohol) on the microemulsion formation to enhance the solubilization. It was found that the addition of polyols and short-chain alcohols could improve oil solubilization of the oil/water microemulsion system. It was concluded that the oil solubilization capacity was dramatically improved by using a suitable nonionic surfactant together with polyols and short-chain alcohols. Tongcumpou *et al.*, (2003a, 2003b) reported that the detergent formulation using the linker concept by using these surfactants to form microemulsions with motor oil in order to obtain ultralow IFT and relatively high solubilization. This selected formulation was found to provide high detergency performance.

### **2.3 Principal Mechanisms of Oily Soil Removal**

Removal of oily soil from fabrics is a complex phenomenon which takes place by a combination of various mechanisms such as roll-up, emulsification, and solubilization.

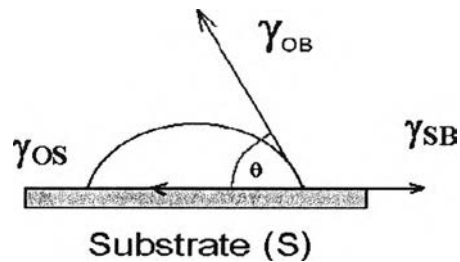
### 2.3.1 Roll-up Mechanism

The roll-up mechanism was first described by Raney and coworkers (1987); this mechanism depends on the wetting properties of aqueous surfactant solutions. The roll-up mechanism is believed to play a major role in oily soil removal (Broze, 1994). Basically, thin layers of the oily soil attach on the fabric surface within a surfactant solution. The contact angle that the liquid soil makes with the substrate is increased by the adsorption of surfactant from the cleaning bath. Many researchers have found that the reduction of IFT at the soil-bath interface ( $\gamma_{OB}$ ) and an increase in contact angle ( $\theta$ ), correlate well with increasing detergency performance.

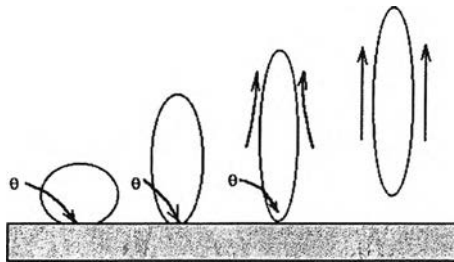
The correlation between IFT and contact angle is given by Equation 2.2, known as Young's equation (Rosen, 2004).

$$\gamma_{SB} = \gamma_{OB} \cos\theta + \gamma_{SO} \quad (2.2)$$

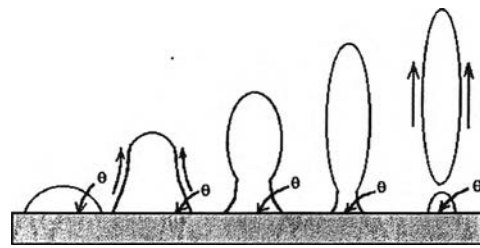
Figure 2.2 illustrates the situation of a liquid soil adhering to the substrate surface in the presence of a cleaning bath. In many cases,  $\gamma_{SB}$  is reduced to point where  $\gamma_{SB} - \gamma_{OS}$  is negative, with resulting increase in  $\theta$  to a value greater than  $90^\circ$ . It is evident that the higher the contact angle, the more easily the soil is removed (Broze, 1994). If the reduction of IFT is so strong that the sum of soil-bath and substrate-bath interfacial tension reaches the soil-substrate IFT, the contact angle is  $180^\circ$  ( $\cos\theta = 1$ ), which means that no soil is left on the substrate (spontaneous perfect cleaning), as known is the roll-up mechanism that is illustrated in Figure 2.3. On the other hand, if the reduction of IFT is so weak, the contact angle is so small; this means that only a small quantity of soil is removed. Such a situation is illustrated in Figure 2.4 is known as the snap-off mechanism.



**Figure 2.2** The contact angle between an oil droplet and substrate in bath.



**Figure 2.3** Roll-up mechanism shows complete removal of oil droplets from substrate by hydraulic currents when  $\theta > 90^\circ$  (Rosen, 2004).



**Figure 2.4** Snap-off mechanism shows incomplete removal of oil droplets from substrate by hydraulic currents when  $\theta < 90^\circ$ . A small droplet remains attached to the substrate (Rosen, 2004).

### 2.3.2 Emulsification

The emulsification mechanism plays an important role in some detergency process (Miller and Raney, 1993). This mechanism can be explained that the direct emulsification of the thick layer of an oily liquid requires the formation of emulsion or agitation to deform the oil-water interface to the extent that individual drops break off (Raney *et al.*, 1987). In addition, the IFT between the oily soil droplet and bath is very low, so the emulsification can be achieved with a minimum of mechanical work. However, emulsification occurs when the contact angle is less than  $90^\circ$ , causing partial drop detachment, illustrated in Figure 2.3. Therefore, the ability of emulsification for oily soil removal is insufficient to keep all the soil from redepositing on the substrate (Azemar, 1996; Rosen, 2004).

### 2.3.3 Solubilization

In particular, the solubilization or oil uptake capacity of a surfactant system is a major mechanism for removing a small amount of oil, which cannot be removed either by roll-up or emulsification. The solubilization occurs to a significant extent only in some cases and always above the CMC of the surfactant system. Oily soil removal from textile surface by solubilization mechanism becomes significant only above the CMC for nonionics and even for some anionics having low CMCs, and reaches its maximum only at several times the CMC. At low bath concentrations only a relatively small amount of oily soil can be solubilized, whereas at high surfactant concentrations (10-100 times the CMC), solubilization is more similar to microemulsion formation and the high concentration of surfactant can accommodate a much larger amount of oily removal.

For detergency application, the surfactant concentration is generally not much above the CMC; consequently, solubilization is almost always insufficient to suspend all the oily soil. When insufficient surfactant is present to solubilize all the oily soil, the remainder is probably suspended in the bath by emulsification. Besides, the maximum solubilization capacity of a given surfactant is also mentioned that it occurs when the surfactant divides equally well between the water and the oily phase. In practice, this happens for a given surfactant system at a temperature referred to as the phase inversion temperature (PIT) (Broze, 1994).

The solubilization depends on the shape of the micelles, the chemical structures of the surfactant and solute, its concentration in the bath, and the temperature. The oil uptake capacity of globular micelles is limited because the addition of oil necessarily results in an increase of the micelle surface exposed to water. Rod-like micelles are much better adapted to a higher oil uptake (Rosen, 2004). A surfactant forming rod-like micelles induces a lower oil-water IFT and accordingly facilitates the transfer of oil from the substrate to the core of the micelles. For nonionic surfactants such as polyethoxylate fatty alcohols, they exhibit a much higher potential for solubilization. The solubilization can result in more complete removal of oily soil from substrate than the emulsification (Azemar, 1996).



## 2.4 Maximum Detergency ( $D_{\max}$ ) and Spreading Effect

Several studies reported that the maximum detergency corresponded to the optimum condition in a Winsor type III system where the lowest oil/water IFT and the highest oil solubilization occur (Raney *et al.*, 1987; Robbins, 1977; Dillan *et al.*, 1980; Azemar, 1996). In a nonionic surfactant system, the maximum detergency was found to achieve at the phase inversion temperature (PIT) (Azemar, 1993). In an anionic surfactant system, the maximum detergency corresponded to the optimum salinity ( $S^*$ ) (Broze, 1994; Solans and Azemar, 1992). The maximum detergency was found to correspond to the microemulsion region which exhibits ultra-low IFT with maximum solubilization power.

However, the  $D_{\max}$  was not always found at the  $IFT_{\min}$  or at the optimum condition (Thompson, 1994). The separate microemulsion phase (middle phase microemulsion) was trapped in fiber bundles, resulting in surfactant loss from the solution. Consequent redeposition of detached oil can take place because insufficient surfactant is present in solution to form stable emulsions of detached oil droplets. Redeposition is promoted when emulsified oil droplets contact fabric and tend to stick to it and wet the fabric surface (Tongcumpou *et al.*, 2005). That is called Thompson effect or spreading effect (the surfactant lost into/onto the fabrics).

The oil film deposited on the surface of the fabric can be indicated by the spreading coefficient ( $S$ ).

$$S = \gamma_{o/w} (\cos\theta - 1) \quad (2.3)$$

When  $S$  is zero, the oil film will spread and coat the surface. At optimal conditions, the contact angle is still close to  $90^\circ$ , but the IFT is ultralow, it can produce a near zero spreading coefficient, which means that it is very likely to form a coating microemulsion film on the surface of the fabric.

The spreading effect was used to explain why the oil removal in the rinse step was almost as high as that in the wash step (Tongcumpou *et al.*, 2003b). It was hypothesized that the spreading effect would occur in the wash step with high

salinity of the microemulsion-based formulation under the ultralow IFT condition. During the wash step, the contact angle of the oil on the fabric surface should progressively increase, resulting in the detachment of the oil droplets. However, owing to the very low IFT, the spreading effect is dominant, thereby causing incomplete oil removal. During the subsequent rinse step, the IFT increases, passing through a composition at which the roll-up mechanism causes additional oil removal and it still obtained the maximum detergency performance with ultralow IFT.

## **2.5 Factors Affecting Oily Soil Removal**

Several factors were found to affect the detergency performance, which are agitation speed, washing time and detergent concentration (Linfield *et al.*, 1962; Germain, 2002). In addition, soil removal from fibrous substrate also depended on the nature of the soil, the order of application, temperature and type of detergent formulation (Webb and Obendorf, 1988).

### **2.5.1 Nature of Oil**

Squalene, a nonpolar oil, was found to be easier to remove from nonpolar fabric surface when it was in a mixture of polar and nonpolar oil as compared to as single nonpolar oil. However, the effect of mixing the polar oil with squalene on the removal of squalene was reversed after aging because the polar oil would be more penetrated into fiber with squalene, resulting in low detergency performance (Scott, 1963). It was observed that the residual oil contained a greater percentage of the nonpolar components than the polar oil. Polar oils tended to be more easily removed in an aqueous detergent system (Gordon, 1968; Powe, 1972; Morris and Prato, 1982).

In addition, the viscosity of oil was observed to affect the oil removal. The oil with lower viscosity is usually removed more rapidly from the substrate than one with a higher viscosity because the oil with low viscosity is higher possibility of mobilization than the oil with high viscosity (Kissa, 1987). The effect of polar oil components in mixed oily soil on detergency performance was further studied (Raney and Benson, 1990). It was suggested that a minimum quantity of polar oil

might be necessary to attain a high oil removal. It was proposed that the different IFT reduction at different types of oils in the mixed oil system influenced the removal of nonpolar/polar oil mixtures. It was found that the highly unsaturated oily soil was easily oxidized upon aging, resulting in increasing oil removal whereas in the case of saturated oils, there were insignificantly differences in the oil removal between aging and without aging. In addition, it was reported that the aging resulted in oils to penetrate deeper into the fabric and fiber structures, causing lowering oil removal (Chi and Obendorf, 1998).

### 2.5.2 Surfactant System

The type of surfactant was observed as a major influence on the detergency performance. An anionic surfactant was found to remove oil from the cotton fabric more effectively than a nonionic surfactant. As expected, anionic surfactants are effective on more polar fiber surfaces. However, both of nonionic and anionic surfactants showed the insignificantly different total oil removal from the polyester/cotton fabric (Obendorf and Klemash, 1982). Based on the study of the detergency performance of triolein by using mixed surfactants, it was found that a mixed surfactant system of a poor surfactant and an efficient surfactant resulted in poor performance in oil removal even though the poor surfactant was only 10% of the total surfactant concentration (Webb and Obendorf, 1988).

In addition, the effects of nonionic surfactant and temperature on detergency performance were studied for nonpolar soils (hexadecane, squalene, and mineral oil) on polyester/cotton fabric. It was found that the detergency performance using the nonionic surfactant as a formulation was strongly depended on temperature and the optimum detergency performance was achieved at the phase inversion temperature or PIT (Solans *et al.*, 1988). It was also reported that the degree of ethoxylation in the structure of nonionic surfactants directly affected the detergency performance: the optimum temperature and detergency performance increased when the degree of ethoxylation of the surfactant increased (Azemar *et al.*, 1993).

The use of surfactant mixture was reported to exhibit a low oil/water IFT, which was considered to provide superior oily soil detergency (Verma and Kumar, 1998). In this study, the oil/water IFT of mixed anionic/nonionic surfactant

system was measured as a function of time. The oil/water IFT was found to decrease as a function of time for all different surfactant blends containing nonionic surfactants. It was proposed that the diffusivity of hydrophobic fraction of nonionic surfactant into the oil phase lead to lowering oil/water IFT. Moreover, it was found that the increasing ratio of nonionic to anionic surfactant in the mixed surfactant system and the higher of EO moles increased detergency performance (Goel, 1998a). In the same year, detergency performance at different ratios of nonionic to anionic surfactant concentration was investigated. It showed that the IFT decreased with increasing the EO moles in the nonionic surfactant. Hence, the minimum IFT was found at a high fraction of nonionic surfactant in the mixture and it exhibited high solubilization of oily soil, which corresponded to the maximum detergency (Goel, 1998b). In terms of effective oily soil removal, anionic and nonionic surfactants tended to perform best on polar and nonpolar soils, respectively (Whang *et al.*, 2001).

### 2.5.3 Salt

Webb and Obendorf (1988) investigated the effect of adding electrolytes on the oily soil removal in detergency process. It was found that the time for any given mineral oil removal by using the mixed system with 0.5 MNaCl was shorter than the anionic alone. Furthermore, the detergent performance as a function of salt was observed. The optimum detergency performance was obtained at the optimum salinity of 10% NaCl which were favorable conditions for microemulsion formation (Solans and Azemar, 1992).

### 2.5.4 Substrate

Christ *et al.* (1994) studied the effect of substrate on oily soil detergency performance. The removal of unaged oily soil was found higher for nylon than cotton or polyester since the polyester is nonpolar while the cotton is high polar. Moreover, the low removal of squalene from cotton was due to morphological characteristics of cotton that made squalene difficult to be removed (Chi and Obendorf, 2001). Interestingly, soil removal from cotton fabrics that had been chemically modified by mercerization and carboxymethylation were studied by

Obendorf and Borsa (2001). It was proposed that the carboxymethylation changed the chemistry of the fiber by increasing the carboxyl group content, this structure changed was believed to reduce the amount of soil deposited in the fiber. In case of the mercerization, it was indicated that the chemical accessibility and hydrophilicity of the fiber structure were responsible for both soil deposition and low removal of lipid soils.

#### 2.5.5 Water Hardness

Water hardness or the presence of polyvalent cations such as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in the bath water is invariably detrimental to the cleaning process because polyvalent cations can precipitate anionic surfactant (Scamehorn and Harwell, 1993; Rosen, 2004). Hardness can adsorb onto the negatively charged substrate and soil reduces their electrical potentials, resulted in impeding soil removal and facilitating its redeposition. In addition, hardness not only can act as linkage between negatively charged substrate and negatively charged soil, thus promoting soil redeposition, but also it can act as linkage between the negatively charged hydrophilic groups of anionic surfactant and the negatively charged soil or substrate, causing adsorption of the former with their hydrophilic groups oriented toward the latter and their hydrophobic groups toward the bath. The adsorption with this orientation results in increases in the IFT at the substrate-bath and soil-bath interfaces which results in increasing the work of adhesion and impeding the roll-up of oily soil.

Moreover, at high polyvalent action concentrations, the corresponding metal salts of anionic surfactants and other anions (e.g. phosphates, silicates) in the bath may precipitate onto the substrate. In some cases, this may mask the presence of soil on the substrate or produce other deleterious effects (Rosen, 2004).

#### 2.5.6 Builders

Builders are another influencing factor for enhancing the cleaning performance. Builders are considered to be of nearly equal importance to surfactants because they support and enhance overall wash performance of the bath by lowering water hardness, controlling alkalinity, buffering the pH, and acting as dispersants, antiredeposition agents, corrosion inhibitors, etc. The primary function of builders is

to counter the detrimental effects of polyvalent cations such as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  on detergency by removing them from solution either as a soluble complex or as a precipitate. Polyvalent cations are introduced into the wash bath mainly by water hardness but may also come from soil or substrate. Most builder salts provide alkalinity to neutralize acid soils, producing soaps which aid further in the detergency process and decrease soil redeposition by stabilization of the dispersed soil (Komaki *et al.*, 2002; Rosen, 2004). It was found the largest difference in soil removal and appearance among the formulations of detergents was based on the presence or absence of builder (Webb and Obendorf, 1988). However, few cleaning studies have focused on the detergency performance of the builder alone, especially true for polyelectrolyte builders. Even though builders have been designed to change the physical and chemical nature of the washing bath, it can also improve the detergency performance of surfactants (Komaki *et al.*, 2002; Webb and Obendorf, 1988).

Tripolyphosphate (TPP) or sodium triphosphate (STPP),  $\text{Na}_5\text{P}_3\text{O}_{10}$ , is the most common historical builder because it is cheap and effective. However, it has the problem for still water about its contribution to eutrophication which results in decreasing the dissolved oxygen in water. Consequently, fish die by insufficiency of oxygen to breathe and subsequently, it causes water pollution by the presence hydrogen sulfide produce by the anaerobic degradation. For turbulent water which has sufficient dissolved oxygen, phosphate will not cause water pollution. Phosphate is highly effective in performance enhancement in cleaning while non-phosphate formulations tend to be less effective.

Ethylenediaminetetraacetic acid (EDTA),  $\text{C}_{10}\text{H}_{16}\text{N}_2\text{O}_8$ , is one of builders which is highly effective. It is a novel molecule for complexing metal ions. It is a polyprotic acid containing four carboxylic acid groups and two amine groups. The unusual property of EDTA has an ability to chelate or complex metal ions in 1:1 metal-to-EDTA complexes.

#### 2.5.7 Other Factors

From the study of detergency formulation and performance conducted by Linfield *et al.* (1962), it was found that an increase in agitation speed,

washing time or detergent concentration, resulted in increasing detergency performance to the maximum levels. It was also noted that for the conditions of washing at 48.9°C, 0.2% detergent and 135 ppm water hardness, the maximum detergency was obtained at 150-170 rpm and 15-20 min washing cycle.

In addition, both mechanical action and detergent concentration affecting the soil removal were reported by Obendorf and Klemash (1982). An increase in either mechanical action or detergent concentration resulted in increasing removal of triolein. In addition, the correlation of PIT with detergency performance was revealed. The maximum detergency was found to occur when the temperature was near the PIT of the system. The combination of solubilization and emulsification was also proposed as the predominant mechanisms for oily soil removal rather than the roll-up mechanism (Raney *et al.*, 1987).

## 2.6 Motor Oil

Motor oil is complex in composition and has high hydrophobicity. It generally consists of at least five main components: n-paraffin, isoparaffin, cycloparaffin, aromatic hydrocarbon, and mixed aliphatic and aromatic ring (Tungsubutra and Miller, 1992). In addition to these main components, several additives are commonly added to the oil to act as rust inhibitor, oxidation inhibitor, detergent-dispersant, viscosity-index improver, pour-point dispersant, and antifoam. The EACN (equivalent alkane carbon number) is a parameter used to characterize the hydrophobicity of different oils. It is an equivalent number of carbons in the complex mixed oil as compared to single component alkane oil. The higher the EACN, the higher the hydrophobicity of the mixed oil is. Wu *et al.* (2000) studied and reported the EACN value of motor oil to be 23.5.

## 2.7 Palm Oil

Palm oil is produced as the second largest world production of vegetable oils and it is widely used as cooking oil and in food industry because of its

competitive price. Therefore, it is considered to be a good representative as a model oily soil on clothes, and kitchenware. The molecular structure of the palm oil consists of fatty acids, which are mainly composed of 44.3% palmitic acid, 38.7% oleic acid, 4.6% stearic acid, 10.5% linoleic acid, 1% myristic acid and 0.9% other (Wang, 1999). It contains the same amount of saturated and unsaturated fatty acids and it is considered as polar oil because of fatty acid in its molecular structures. The polar property of palm oil makes its phase behavior different from typical petroleum-based hydrocarbons and the bulky structure of the fatty acids contained in the palm oil makes it more difficult to be solubilized.