

CHAPTER IV RESULTS AND DISCUSSION

4.1 Zeta potential results

Figure 4.1 shows the zeta potential of the ferric oxide in MES solutions at different MES concentrations and pH values. The zeta potential of ferric oxide became more negative with increasing MES concentration. For any given MES concentration, the zeta potential of ferric oxide became more negative with the increasing solution pH. The results can be explained that the negative charge of the hydrophilic group of MES adsorbing on the ferric oxide surface which is responsible for the increase in negative charge on the ferric oxide surface.

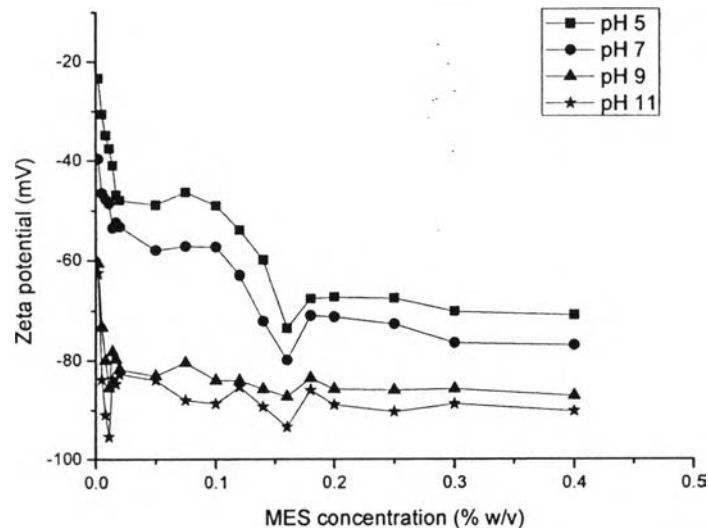


Figure 4.1 Zeta potential of ferric oxide in MES solution at 30°C and various MES concentrations and different pH values.

As shown in Figure 4.2, the zeta potential of the ferric oxide in AE9 solution also becomes more negative with increasing AE9 concentration. For any given AE9 concentration, the zeta potential of the ferric oxide becomes more negative with the increasing solution pH. The results can be explained that the AE9

adsorb onto the ferric oxide surface by using hydrophilic head group toward the surface with the bilayer structure at high MES concentration, leading to slightly increases negative charge. In a comparison between the MES and AE9, the MES gives higher effect on the surface charge than the AE9.

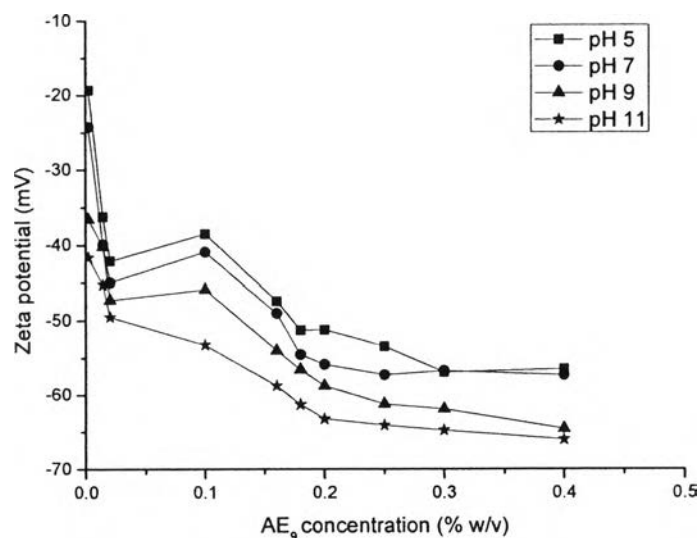


Figure 4.2 Zeta potential of ferric oxide in AE₉ solution at various AE₉ concentration and pH values.

Figure 4.3 shows the zeta potential of the three studied fabrics as a function of equilibrium pH. The PZC is the pH corresponding to the zeta potential equal to zero. From Figure 4.3, the PZC values are 2.9, 2.6 and 2.3 for cotton, blend polyester cotton and polyester, respectively which good agreement with previous study [2]. Figure 4.4 shows the zeta potential at different solution pHs. From Figure 4.4 the PZC of the ferric oxide is about 6.1 which is much higher than those of the test fabrics.

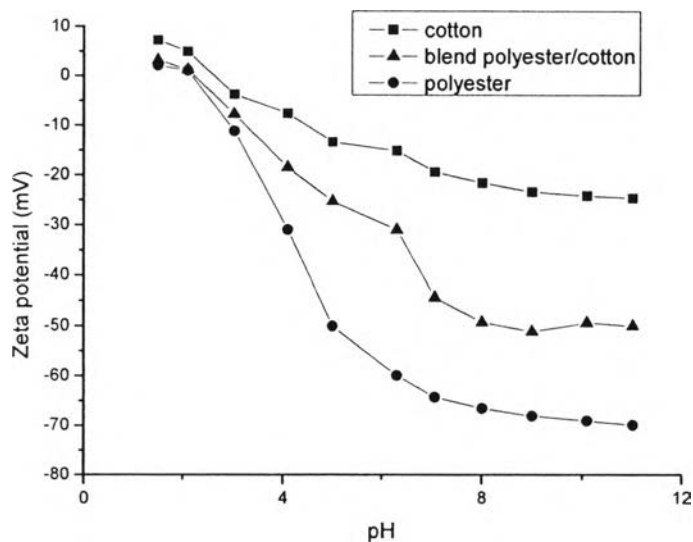


Figure 4.3 Zeta potential of fabrics in deionized water at 30°C and various pH value.

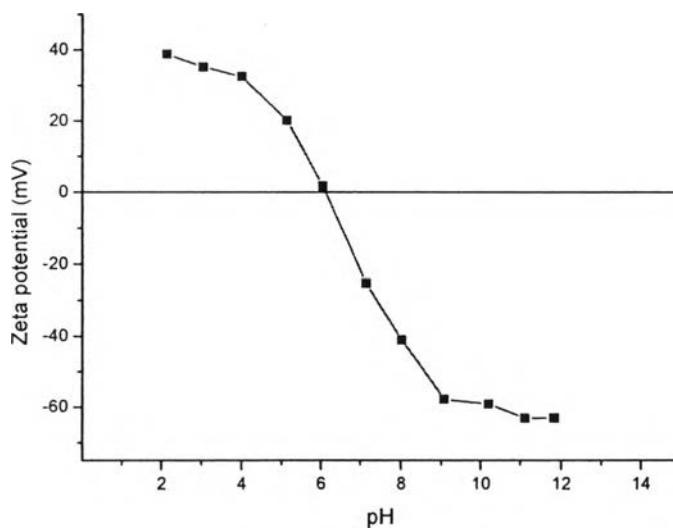


Figure 4.4 Zeta potential of ferric oxide in deionized water at various pH value.

In comparisons among three studied fabrics, the cotton fiber exhibited the highest zeta potential value (-24.6 mV, the lowest negatively zeta potential). This fiber is negatively charged due to the presence of hydroxyl and carboxy groups. The functional groups influence the zeta potential, but the fiber swelling has an important role also. The interfibrillar swelling enlarges the surface area, and causes the shift plane into liquid phase lowering the zeta potential [2]. The polyester fiber exhibited

the highest negative zeta potential (-69.9 mV), this is in good agreement with previous study, in which the zeta potential of the higher hydrophobic fiber is larger than that of hydrophilic fibers due to hydration capacity [8].

4.2 Surfactant adsorption isotherm results

4.2.1 MES adsorption isotherms

Figure 4.5 shows the adsorption isotherm of MES on the ferric oxide at different pH values. The CMC of MES is 0.012% (12 mg/l), as shown in Figure 4.6. For any given solution pH, the amount of MES adsorbed increased with increasing MES concentration and reached a maximum when the MES concentration was greater than the CMC. The experimental results also showed clearly that an increase in solution pH decreased the MES adsorption on the surface of the ferric oxide. This is because the surface charge of ferric oxide becomes more negative especially at pH 11, leading to decreasing the adsorption of MES. However the effect of pH on the MES adsorption onto ferric oxide is insignificant at $\text{pH} < 9$. This is because the surface of ferric oxide exhibits the similar value of surface charge at $\text{pH} < 9$, as shown in Figure 4.1. However, the MES at $\text{pH} > 9$ can hydrolyze to form the disodium salt of sulfonated fatty acid [11]. When the MES has the form of the disodium salt, the hydrophilic groups become more negative due to the presenting of the new one of sulfonated fatty acid sodium salt, resulting in the increasing of repulsion between the negative charge on the ferric oxide surface and the hydrophilic group of MES. Hence the MES adsorption on ferric oxide surface shows the lowest adsorption density at pH 11.

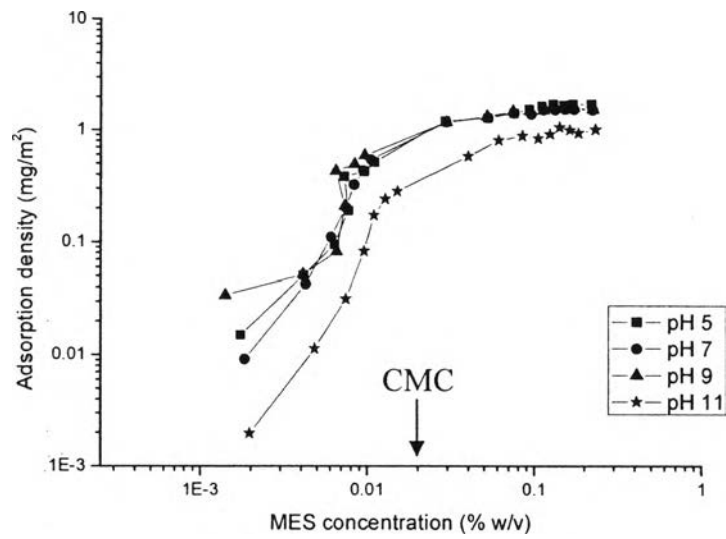


Figure 4.5 Adsorption Isotherm of MES on ferric oxide at 30°C and various pH values.

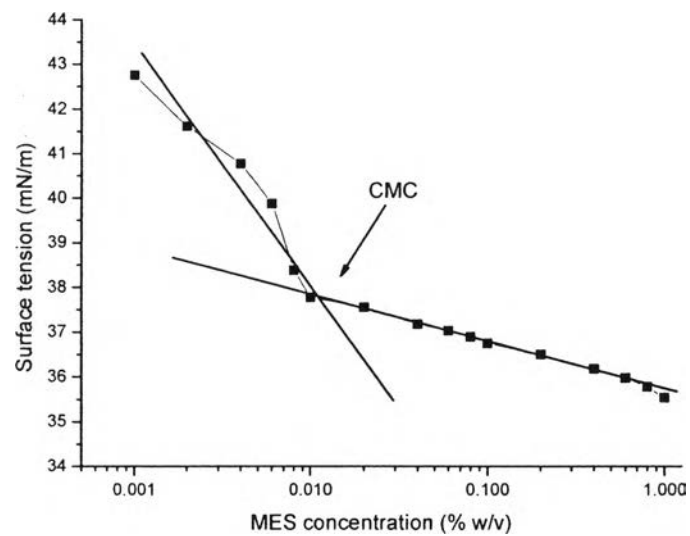


Figure 4.6 Surface tension of MES at 30°C and various concentration.

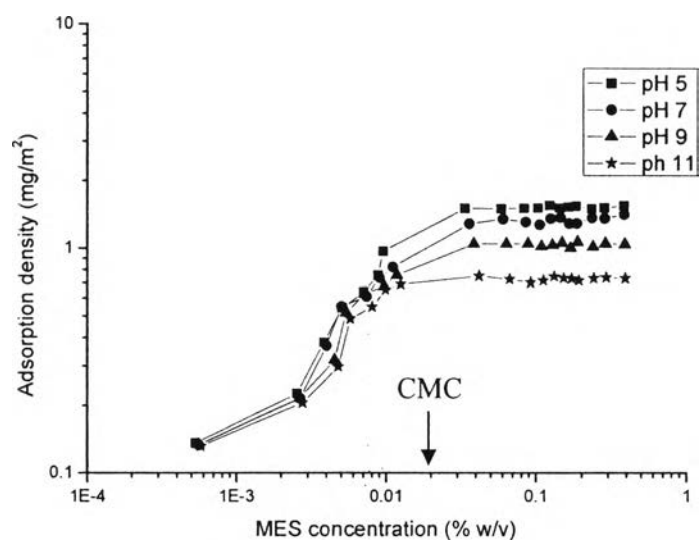


Figure 4.7 Adsorption Isotherm of MES on cotton fiber at 30°C and various pH values.

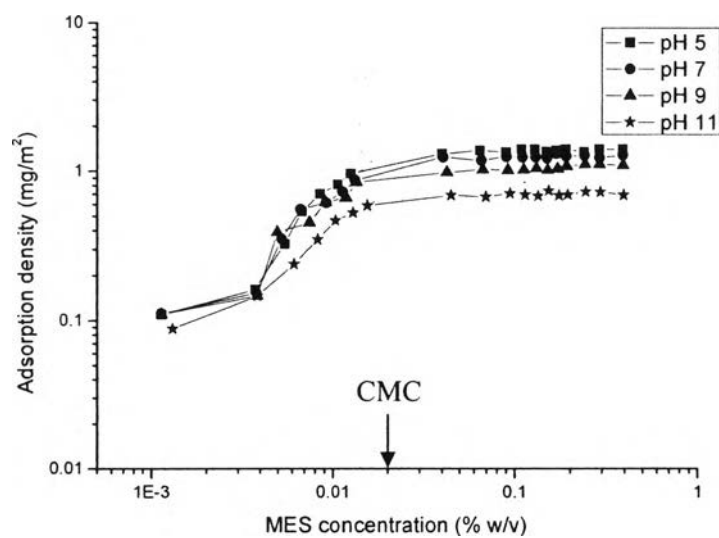


Figure 4.8 Adsorption Isotherm of MES on blend polyester/cotton fiber at 30°C and various pH values.

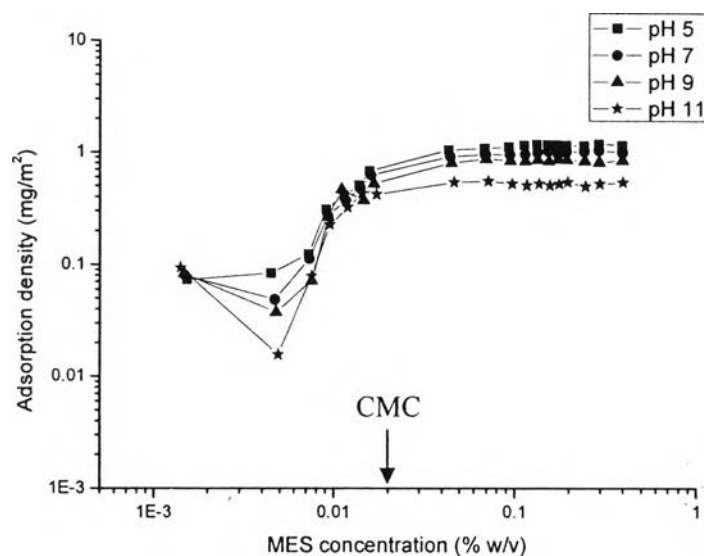


Figure 4.9 Adsorption Isotherm of MES on polyester fiber at 30 °C and various pH values.

Figure 4.7 shows the MES adsorption onto the cotton fabric at different solution pH values. For the MES adsorption, the effect of solution pH on the cotton fabric was much higher than that on ferric oxide. In a comparison among three test fabrics and the ferric oxide, the adsorptions of MES showed the lowest adsorption density at pH 11. This is due to the presence of the disodium salt of sulfonated fatty acid. Figures 4.8 and 4.9 show the MES adsorption on the polyester/cotton blend and the polyester, respectively. In comparisons among the three fabrics, the degree of MES adsorption was found to be cotton > polyester/cotton blend > polyester which correspond to the degree of hydrophilicity of the studies fabric: cotton > polyester/cotton blend > polyester.

4.2.2 Nonionic surfactant adsorption isotherm

The adsorption isotherms of the AE9 on the ferric oxide at various pH values are shown in Figure 4.10. The surfactant adsorption was saturated at the CMC (0.012 %w/v) which is in good agreement with the CMC, as shown in Figure 4.11. In Figure 4.10, the adsorption density of the AE9 on the ferric oxide is insignificantly different in each pH value of surfactant solution. The AE9 adsorption on the ferric

oxide slightly increased with decreasing solution pH. The maximum amount of AE9 surfactant adsorbed per unit area of ferric oxide of 1.36 mg/m^2 was lower than the maximum adsorption density of MES. The insignificant effect of solution pH on the AE9 adsorption onto the ferric oxide is attributed from the neutral charge of the AE9.

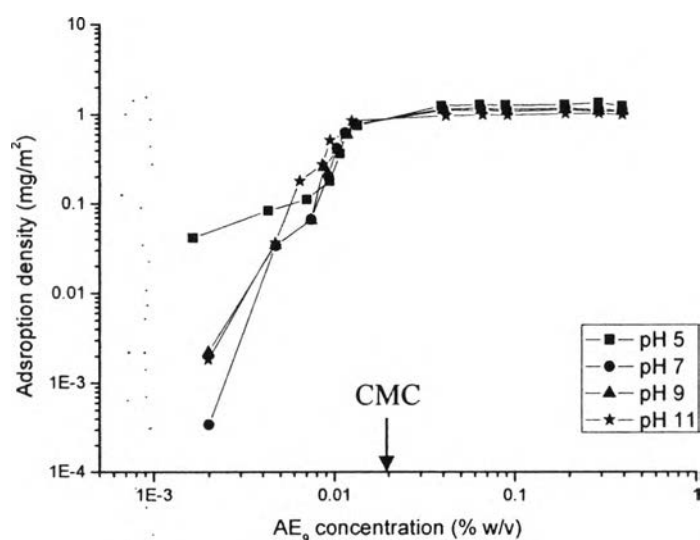


Figure 4.10 Adsorption Isotherm of AE9 on ferric oxide at 30°C and various pH values.

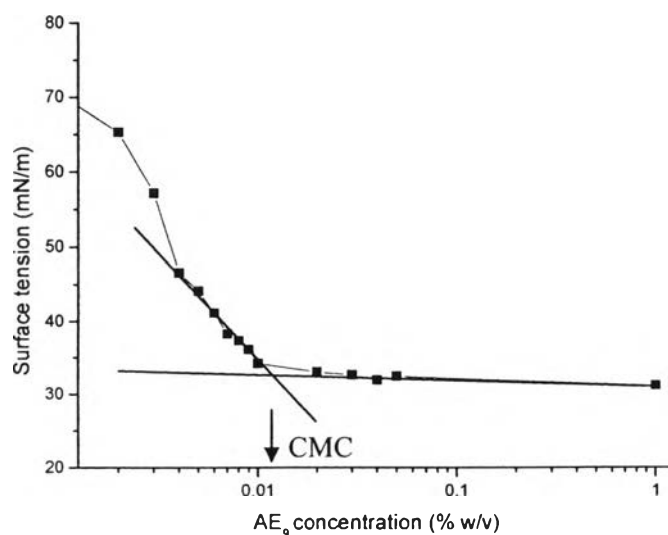


Figure 4.11 Surface tension of AE9 at 30°C and various concentrations.

Figures 4.12, 4.13 and 4.14 show the AE9 adsorption isotherm on the three fabrics. The AE9 adsorption on these three fabrics showed the similar trends as compared to the case of MES. Interestingly, the effect of solution pH on the MES adsorption on any given fabric was found to be higher than that on the AE9 adsorption. For any given type of fabric and solution pH, the maximum adsorption of MES was found to be significantly higher than that of AE9.

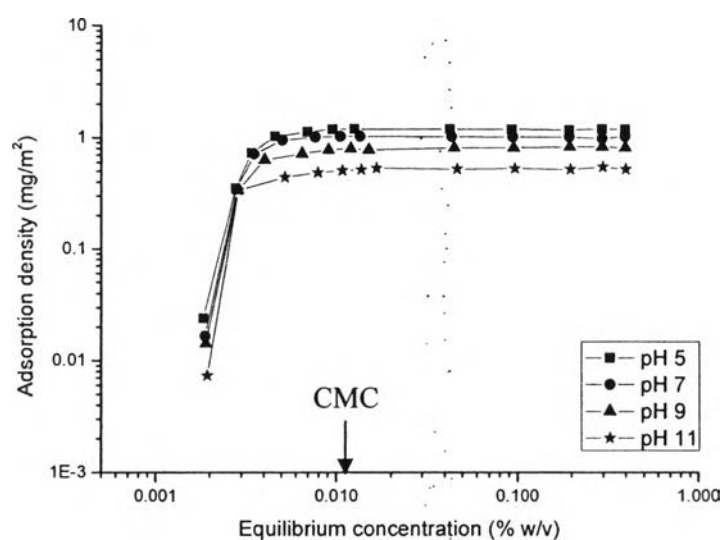


Figure 4.12 Adsorption Isotherm of AE9 on cotton fiber at 30°C and various pH values.

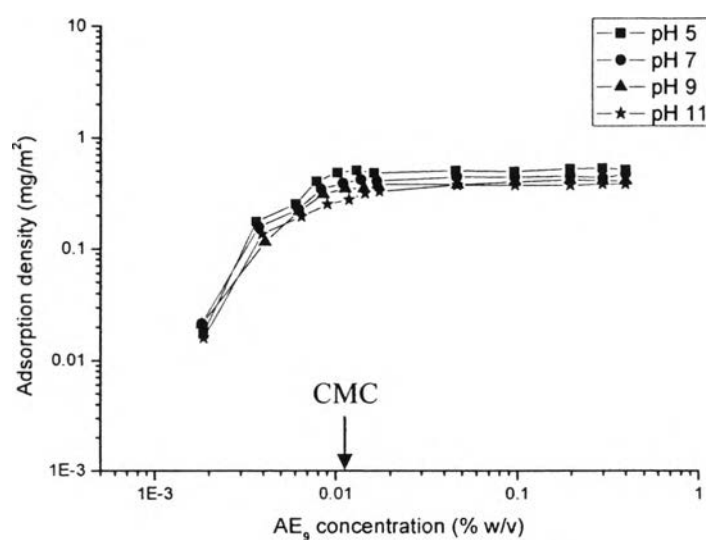


Figure 4.13 Adsorption Isotherm of AE9 on blend polyester-cotton fiber at 30°C and various pH values.

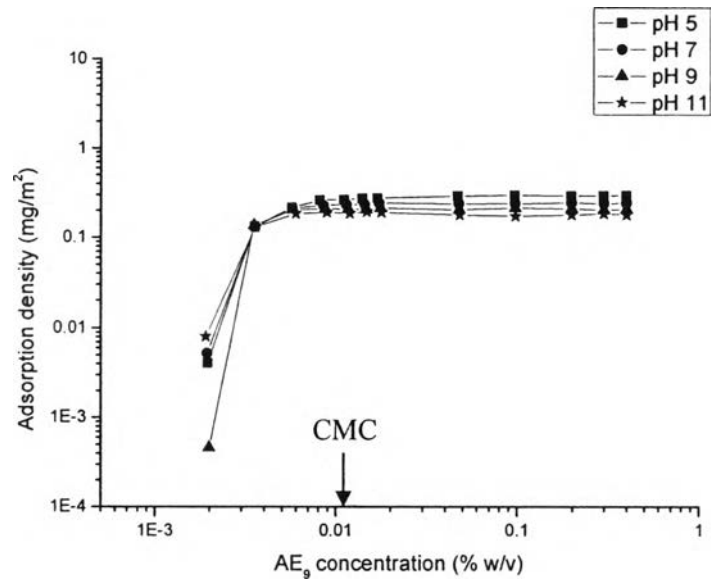


Figure 4.14 Adsorption Isotherm AE9 on polyester fiber at 30°C and various pH values.

4.3 Detergency performance results

4.3.1 Detergency performance of MES

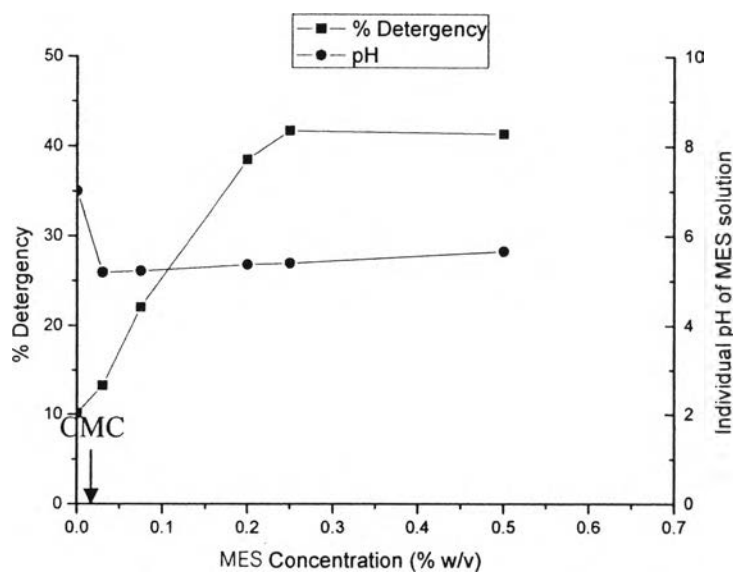


Figure 4.15 %Detergency on cotton fabric at different MES concentrations at 30°C without pH adjustment.

Figure 4.15 shows detergency performance of the MES on cotton fabric at different concentration without pH adjustment. The % detergency increased with increasing MES concentration and leveled off when the MES concentration exceeded 0.25 %w/v. The presence of the MES was found to reduce the solution pH from 7 to around 5.5 and an increase in MES concentration increased slightly the solution pH.

Figure 4.16, shows the detergency performance of the MES on the blend polyester/cotton fabric at different concentration without pH adjustment. Similar to the cotton fabric for the blend polyester/cotton, the %detergency increased with increasing MES concentration and leveled off when the MES concentration exceeded 0.25 %w/v.

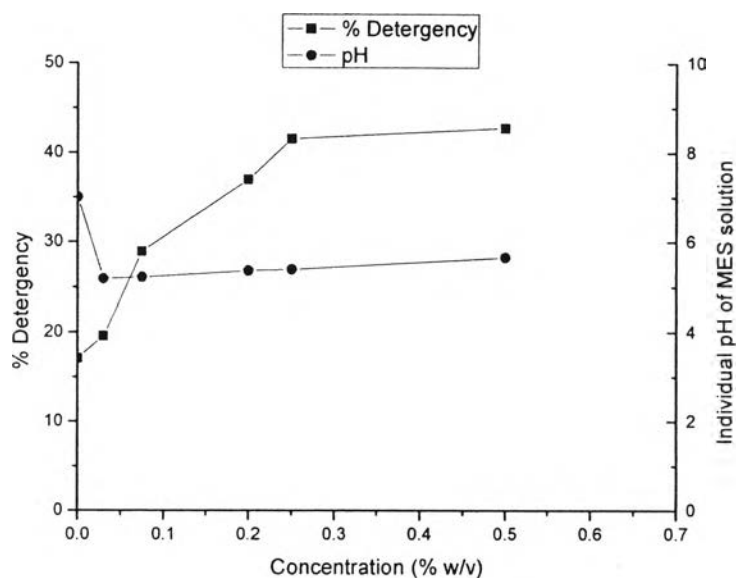


Figure 4.16 %Detergency on blend polyester/cotton fabric at different MES concentrations and 30°C without pH adjustment.

Figure 4.17, shows the %detergency performance of the MES on the polyester fabric at different concentrations without pH adjustment. Similar to both the fabrics, %detergency increased with increasing MES concentration and leveled off when the MES concentration exceeded 0.25 %w/v.

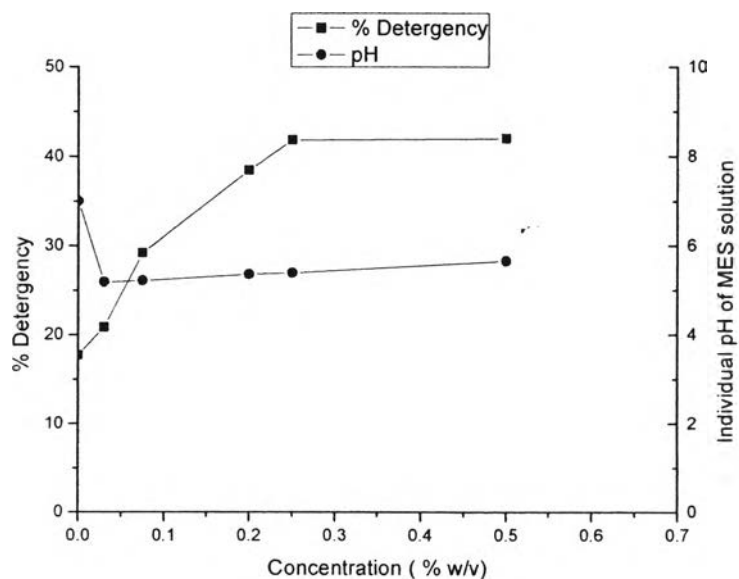


Figure 4.17 %Detergency on polyester fabric at different MES concentrations and 30°C without pH adjustment.

The detergency performance of ferric oxide removal in terms of %detergency as a function of MES concentration and solution pH on the three studied fabrics is shown in Figures 4.18, 4.19 and 4.20. In Figure 4.18, for ant given MES concentration, an increase in solution pH increased %detergency. For any given type of the testing fabrics and solution pH values, the %detergency increased with increasing MES concentration and leveled off when the MES concentration exceeded 0.25 %w/v. An increase in solution pH increased quite significant of %detergency for the testing fabrics. In a comparison among the three fabrics, the highest detergency performance was found to be 63% for the cotton. For the polyester or blend polyester-cotton, the detergency performance was found to be around 58% with good agreement with previous study [43]. The results can be explained in that the cotton fabric has the hydroxyl and carboxyl groups, leading to the interfibrillar swelling, causing the further reducing soil–substrate interactions [9].

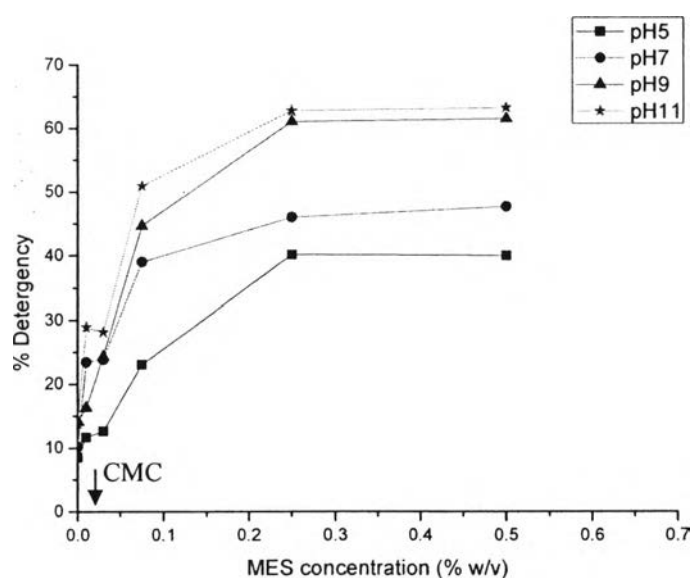


Figure 4.18 %Detergency on cotton fabric at different MES concentrations and solution pH values and 30°C.

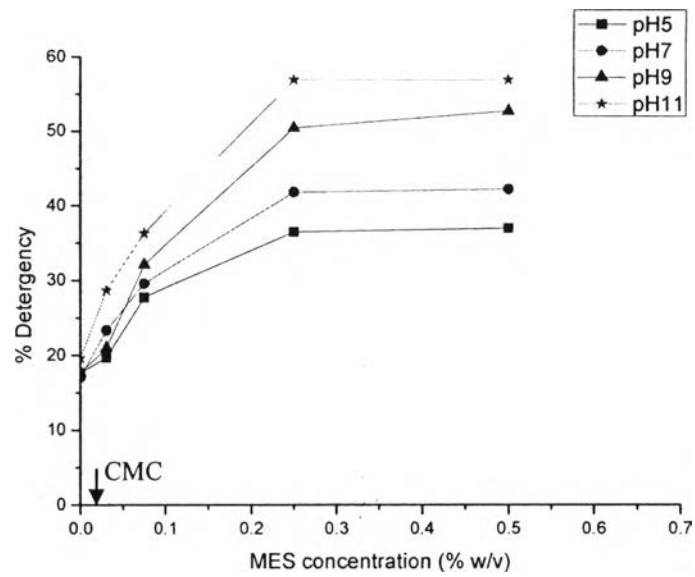


Figure 4.19 %Detergency on blend polyester/cotton fabric at different MES concentrations and solution pH values and 30°C.

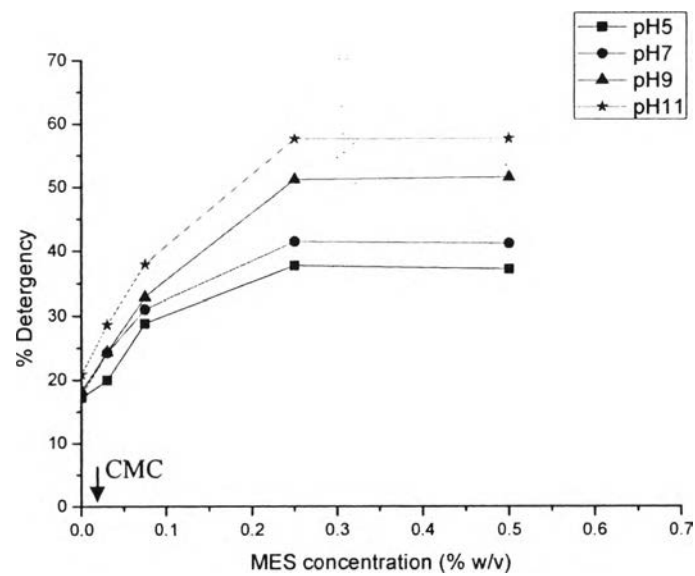


Figure 4.20 %Detergency on polyester fabric at different MES concentrations and solution pH values and 30°C.

4.3.2 Detergency Performance of AE9

Figures 4.21, 4.22 and 4.23 show the detergency performance of the AE9 on the cotton, blend polyester/cotton and polyester fabrics at different concentrations without pH adjustment. The %detergency increased with increasing AE9 concentration and leveled off when the AE9 concentration exceeded 3%w/v. An increase in AE9 concentration also increased the solution pH for all fabrics.

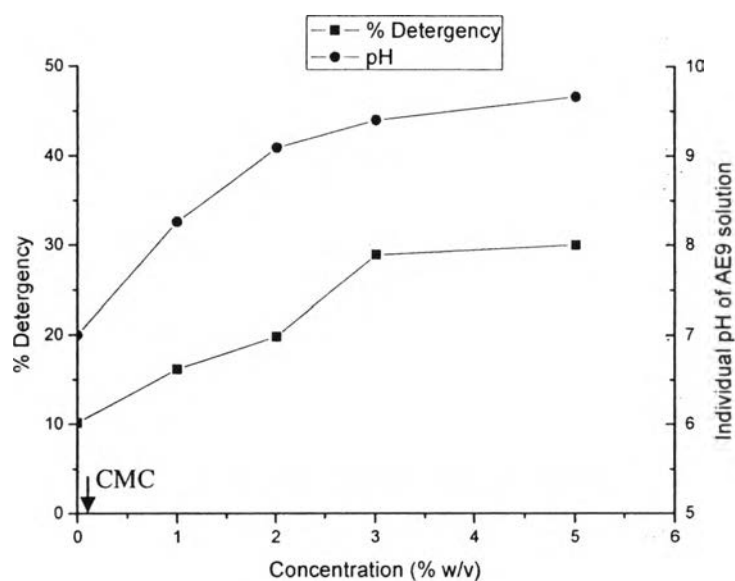


Figure 4.21 %Detergency on cotton fabric at different AE9 concentrations and 30°C without pH adjustment.

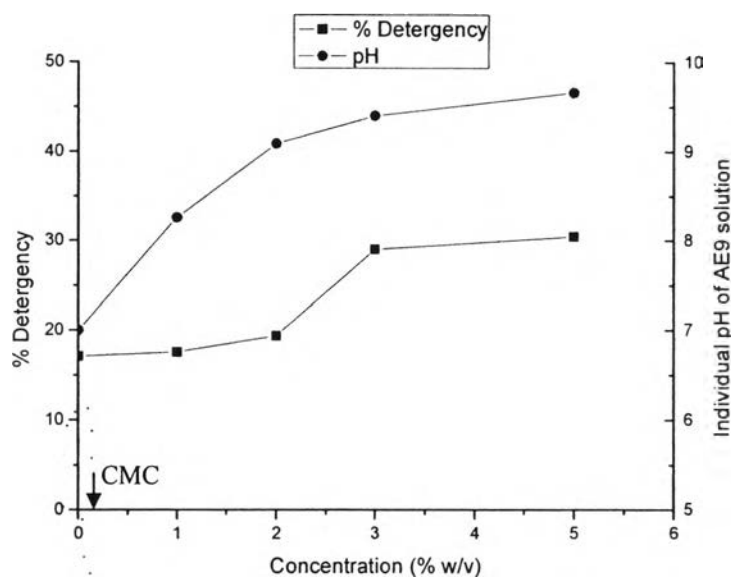


Figure 4.22 %Detergency on blend polyester/cotton fabric at different AE9 concentrations and 30°C without pH adjustment.

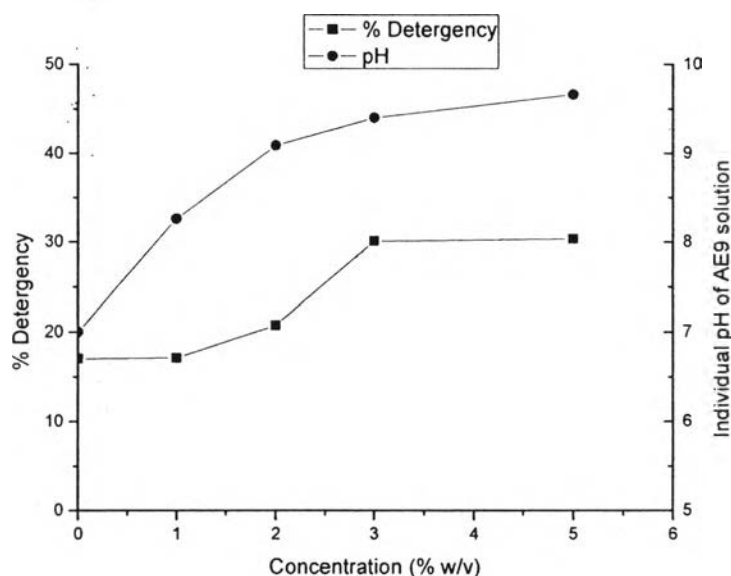


Figure 4.23 %Detergency on polyester fabric at different MES concentrations and 30°C without pH adjustment.

Figures 4.24, 4.25 and 4.26 show the effect of AE9 concentration and pH value on the detergency performance for the three studied fabrics. It was found that the highest %detergency is 41% at pH 11 and 2.5%w/v of the AE9. The AE9 has no charge on the molecular structure, resulting in lower zeta potential of the ferric oxide present as compared with the MES, as shown in Figure 4.1 and 4.2. Thereby

there adsorbed AE9 molecules on the ferric oxide the fabric surfaces have lower the repulsion than that of the MES. Hence, that is why the MES showed higher %detergency than the AE9. However the use of higher AE9 concentrations causes the steric effect and higher repulsion force between the ethylene oxide group of AE9 and the ferric oxide surface including fabric surface. Thus, ferric oxide removal can be improved. The % maximum detergency of the cotton, polyester and blend polyester/cotton fibers are 41%, 39% and 38%, respectively. The highest %detergency can be found on the cotton fabric. The detergency performance of the AE9 with these three fabrics showed the similar trends as compared to the case of the MES.

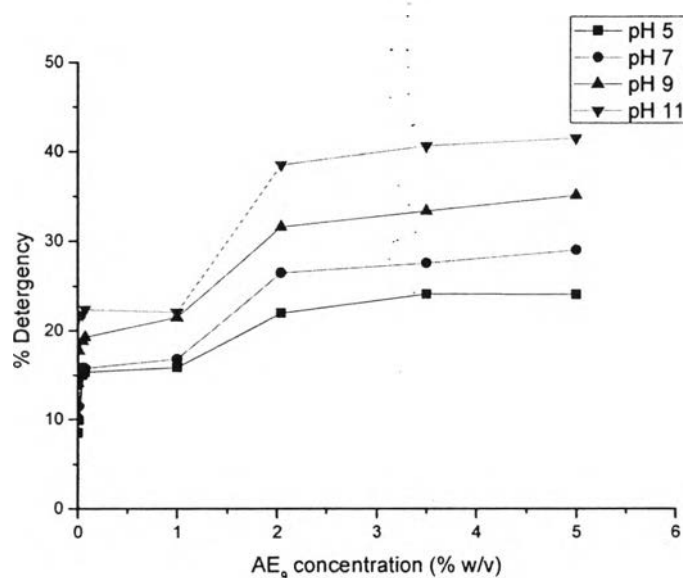


Figure 4.24 %Detergency on cotton fabric at different AE9 concentrations and solution pH values and 30°C.

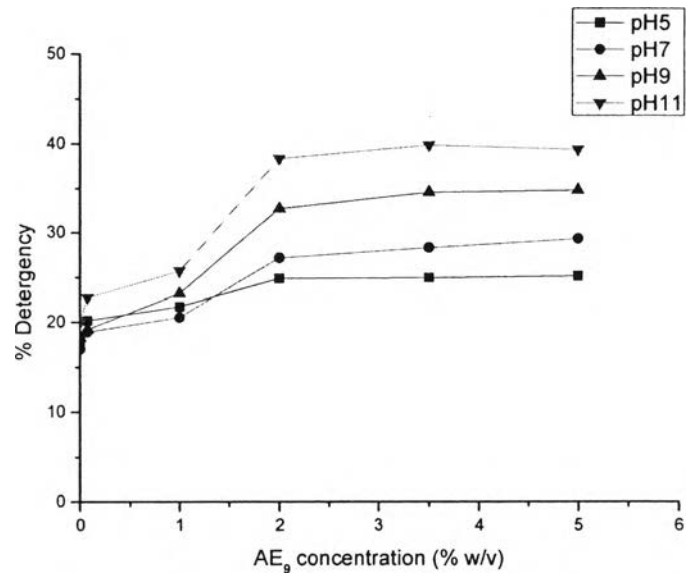


Figure 4.25 %Detergency on polyester fabric at different AE9 concentrations and solution pH values and 30°C.

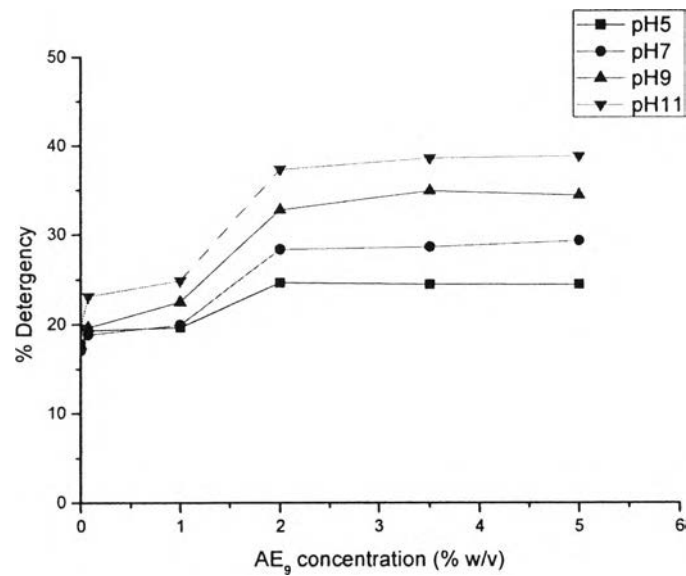


Figure 4.26 %Detergency on blend polyester/cotton fabric at different AE9 concentrations and solution pH values and 30°C.

4.3.3 Detergency performance comparison

Figures 4.27, 4.28 and 4.29 show the %detergency performance of the LAS on the cotton, blend polyester/cotton and polyester fabric at different concentration without pH adjustment. The %detergency increased with increasing LAS concentration and leveled off when the LAS concentration exceeded 0.5%w/v. An increase in LAS concentration also increased significantly the solution pH for all test fabrics.

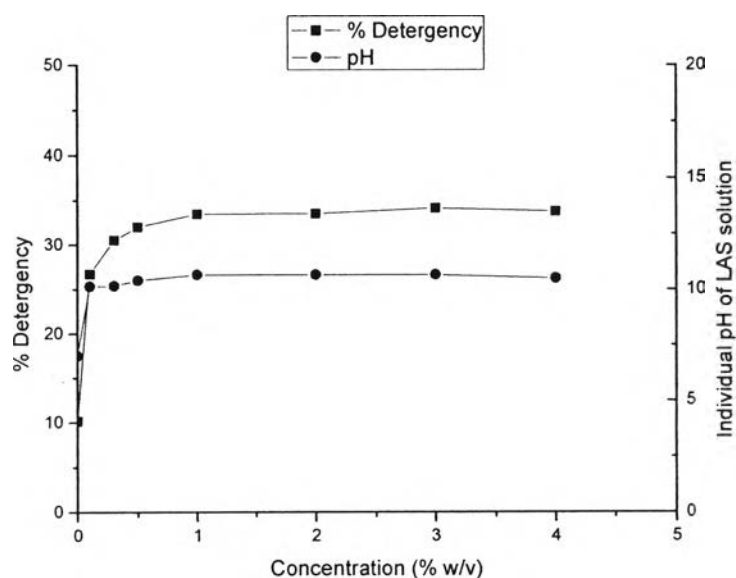


Figure 4.27 %Detergency on cotton fabric at different LAS concentrations and 30°C without pH adjustment.

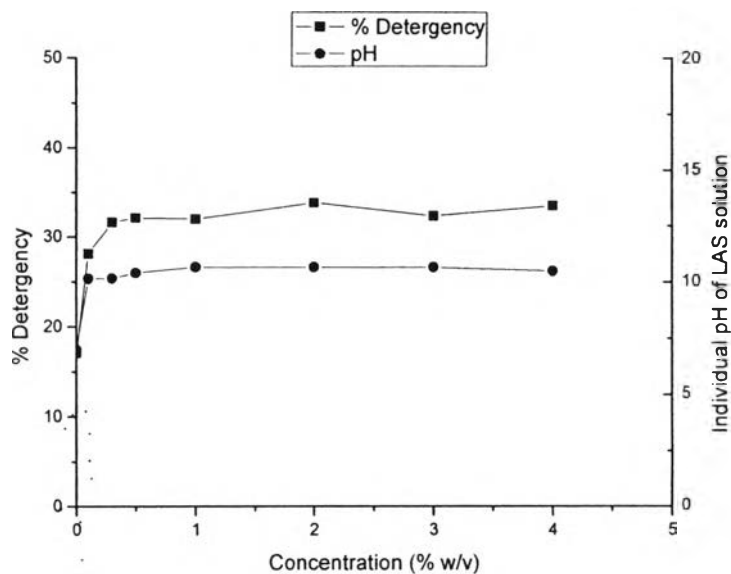


Figure 4.28 %Detergency on blend polyester/cotton fabric at different AE9 concentrations and 30°C without pH adjustment.

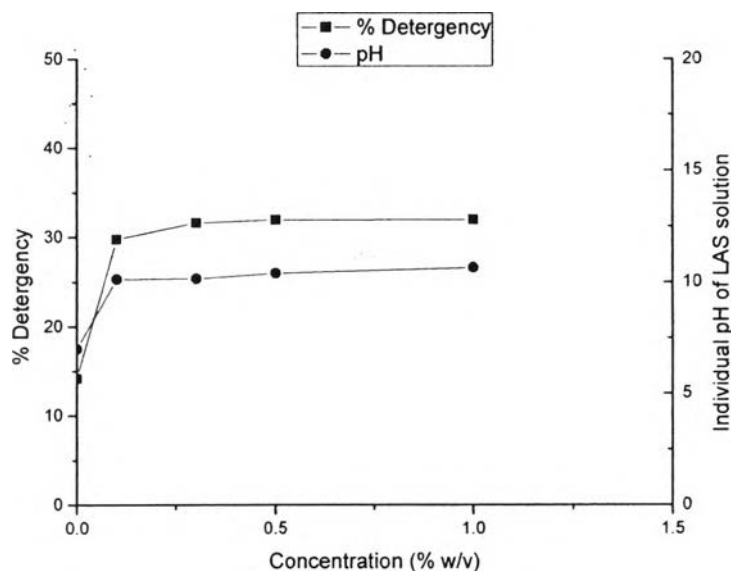


Figure 4.29 %Detergency on polyester fabric at different MES concentrations and 30°C without pH adjustment.

The detergency performance of ferric oxide removal in terms of %detergency as a function of LAS concentration on the three studied fabrics is shown in Figures 4.30, 4.31 and 4.32. In a comparison in detergency among the three testing fabrics shown in Figures 4.30, 4.31 and 4.32, the highest detergency

performance was found to be 39% on the cotton. For the polyester or blend polyester-cotton, the detergency performance was found to be around 36%. The detergency performance of the LAS with these three fabrics showed the similar trends as compared to the case of the MES.

The detergency performance of ferric oxide removal in terms of %detergency as a function of the commercial detergent concentration on the three studied fabrics is shown in Figures 4.33. In a comparison among the three fabrics, the highest detergency performance was also found to be 55% for the cotton.

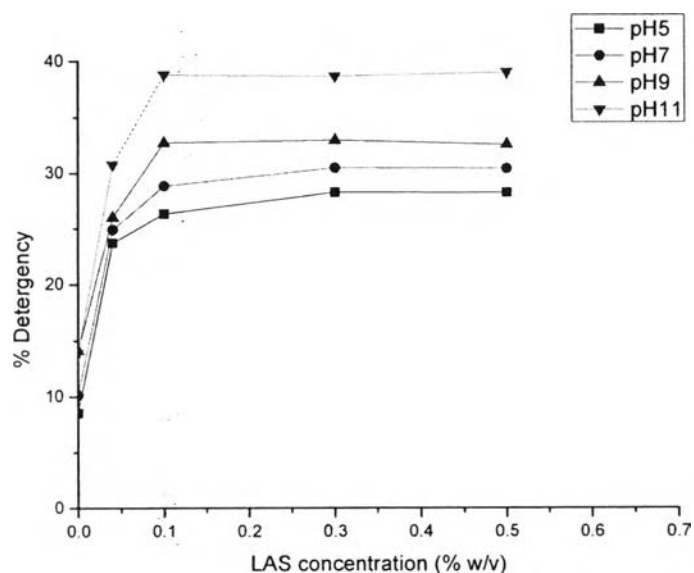


Figure 4.30 %Detergency on cotton fabric at different LAS concentrations and solution pH values and 30°C.

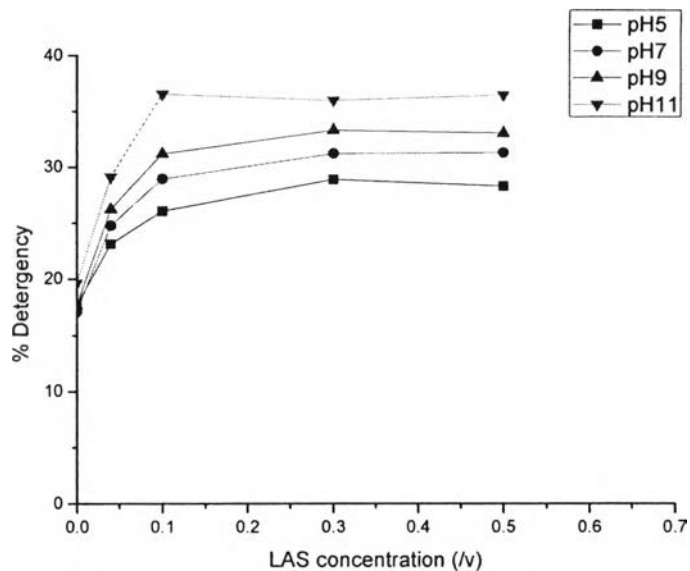


Figure 4.31 %Detergency on blend polyester/cotton fabric at different LAS concentrations and solution pH values and 30°C.

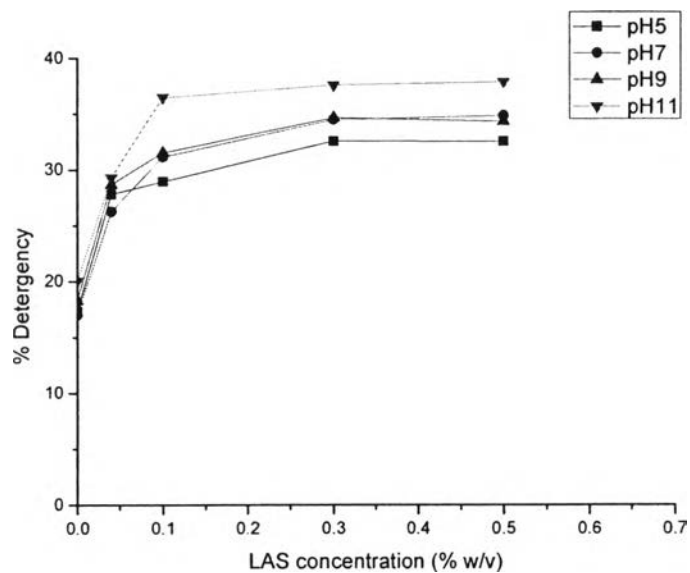


Figure 4.32 %Detergency on polyester fabric at different LAS concentrations and solution pH values and 30°C.

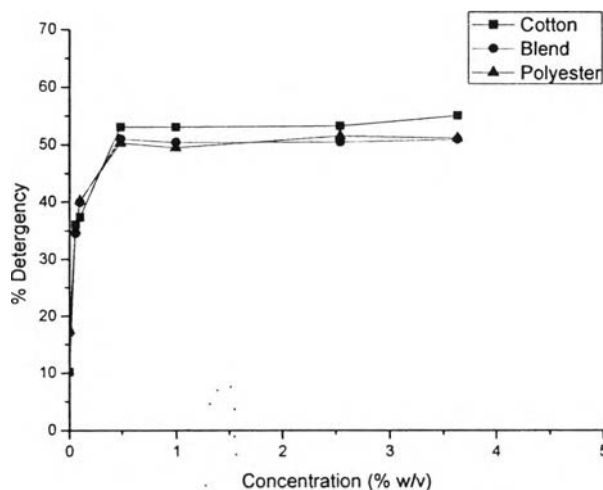


Figure 4.33 %Detergency on cotton, blend polyester/cotton and polyester fabric at 30°C and different commercial detergent concentrations and solution pH values.

Figure 4.34 shows comparisons of detergency performance of the MES, the AE9, the LAS and the commercial detergent on cotton, blend polyester/cotton and polyester fabrics at their optimum concentrations. The comparison came from the highest detergency performance of each surfactant. Among the four test surfactants, as shown in Figure 4.34, the highest detergency performance was found with the MES for all studied fabrics. The commercial detergent showed %detergency lower than the MES. Both the AE9 and the LAS showed the %detergency nearly the same and lower than the commercial detergent. In a comparison in detergency among the three testing fabric, cotton shows the highest %detergency performance which is in good agreement with previous study [43].

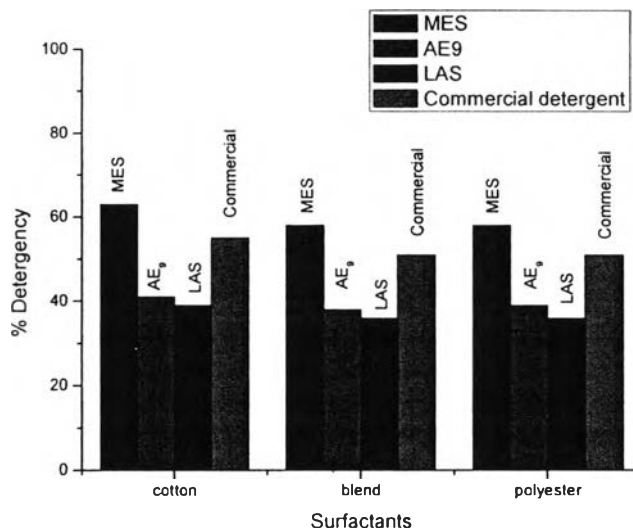


Figure 4.34 %Detergency on cotton, polyester/cotton blend and polyester fabrics at various surfactant types [Surfactant concentrations of 0.25, 2.0, 0.1 and 0.5 %w for MES, AE9, LAS, and commercial detergent, respectively. Temperature 30 °C with pH 11].

4.4 Contact angle Results

In order to obtain a better understand the mechanism of particulate soil detergency, contact angle was investigated. In this experiment, the two test fabrics: polyester and blend polyester/cotton were measured for contact angle since both the ferric oxide and cotton fabric cannot be measured for contact angle. This is because of the hydrophilicity on their surfaces.

From Figure 4.35 and 4.36, the contact angles of the MES solution in the surface of the blend polyester/cotton fabric decreased with increasing MES concentration and leveled off when the MES solution reached the CMC. At pH 11, the MES has a slightly higher of the contact angle than those of other pH levels. The effect of pH was found to be insignificant as compared with MES concentration. The presence of MES caused a great reduction in the contact angle, inducing the improvement of wettability. As a result, both adsorption and detergency performance can be increased.

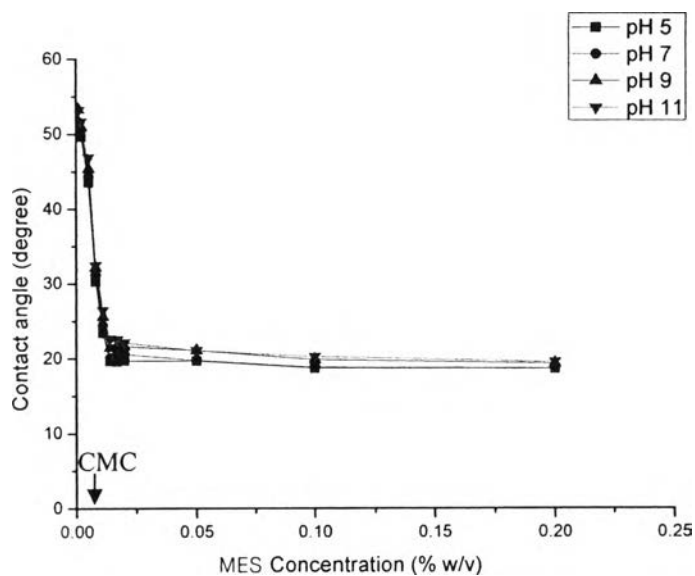


Figure 4.35 Contact angles of MES solution on blend polyester/cotton fabric at 30°C and different MES concentration and pH values.

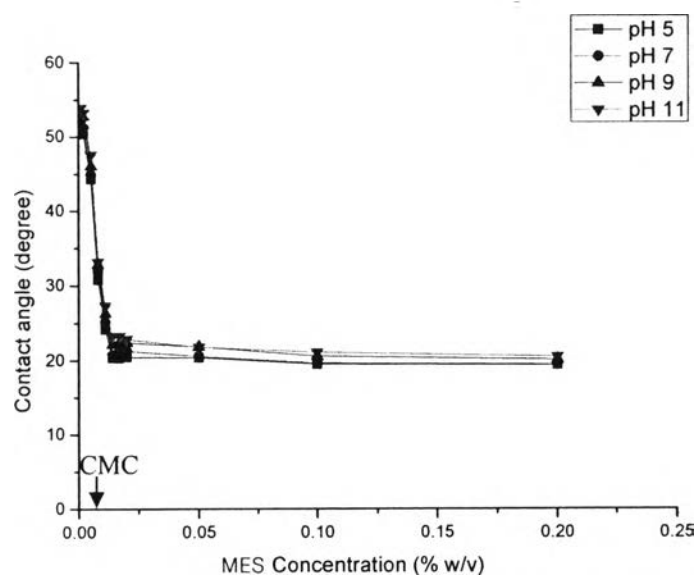


Figure 4.36 Contact angles of MES solution on polyester fabric.

From Figure 4.37 and 4.38, the contact angles of AE9 solution on these two surfaces showed the similar trends as compared to the case of the MES. In addition for any given type of surface, the contact angle of AE9 solution was found

to be significantly higher than the contact angle of MES solution, suggestion that the MES can provide a better wettability than the AE9.

This is an explanation why the MES could provide a better detergency in the removal of ferric oxide particles than the AE9.

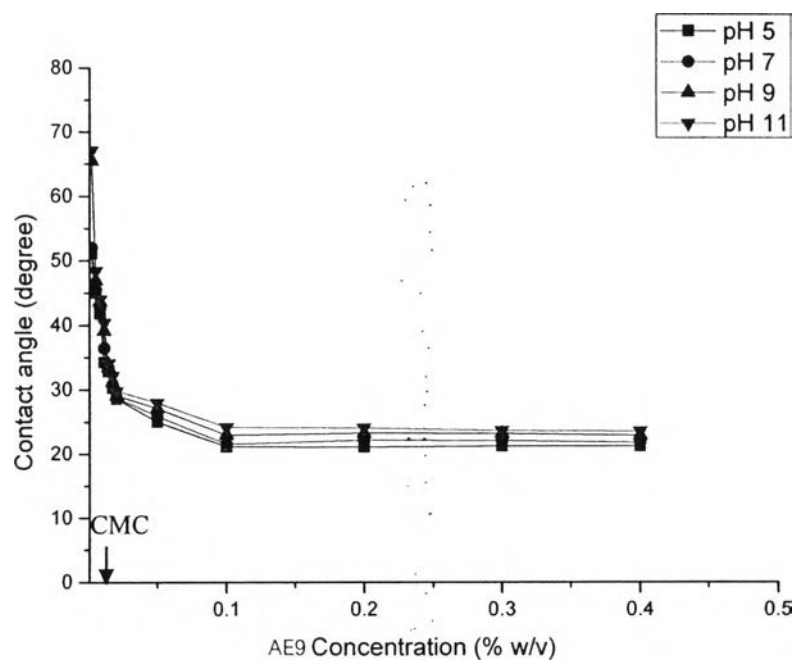


Figure 4.37 Contact angle of AE9 solution on blend polyester/cotton.

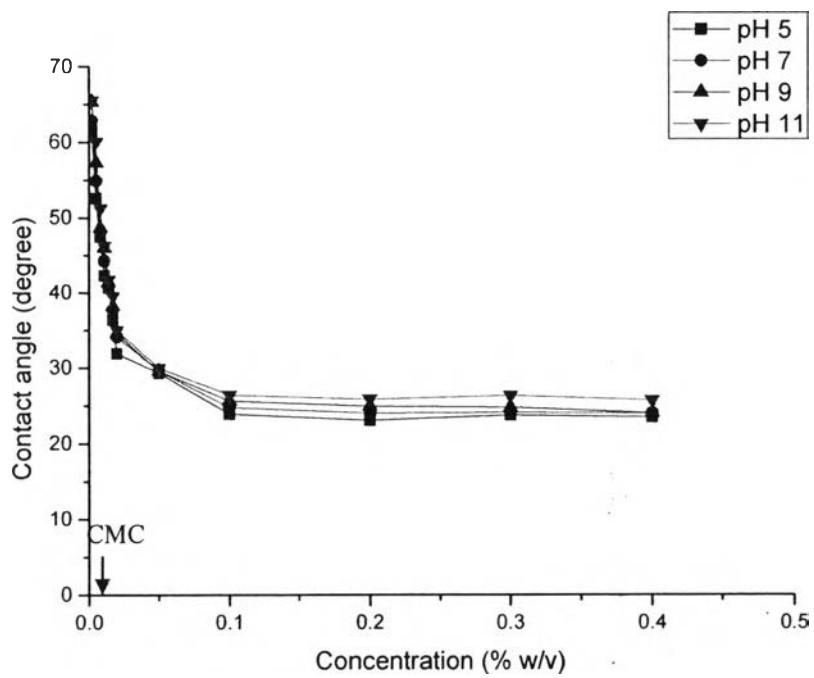


Figure 4.38 Contact angle of AE9 solution on polyester.