

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Effectiveness of Deinking with Surfactant-free Solution

Blue color ink printed plastic samples were shaken with surfactant-free solution at pHs of 10, 11 and 12 for about three days continuously. No significant deinking occurred at all pH levels with or without adding abrasive. Surfactants may be needed to add to the water to reduce the interfacial tension to a reasonable value to allow water to wet the ink. It has been found that for water-based ink on polyethylene film, high pH surfactant-free solutions result in partial deinking (5). However, consistent with the results here, these solutions did not effectively removed solvent-based inks (5).

From ATR-FTIR spectra, for complete deinking, the transmittance spectra of deinked plastic samples should be expected to be the same as the transmittance spectrum of non-printed plastic samples. As shown in Figure 4.1, spectrum (c) of deinked plastic surface is very similar to spectrum (b) of the printed plastic surface which shows that much of the ink has remained on the surface. A more quantitative evaluation of the deinking process can be obtained by an optical scanning method and the results are shown in Figure 4.2. Results were also evaluated on a gravimetric basis. The experimental data and results are shown in the Appendix.

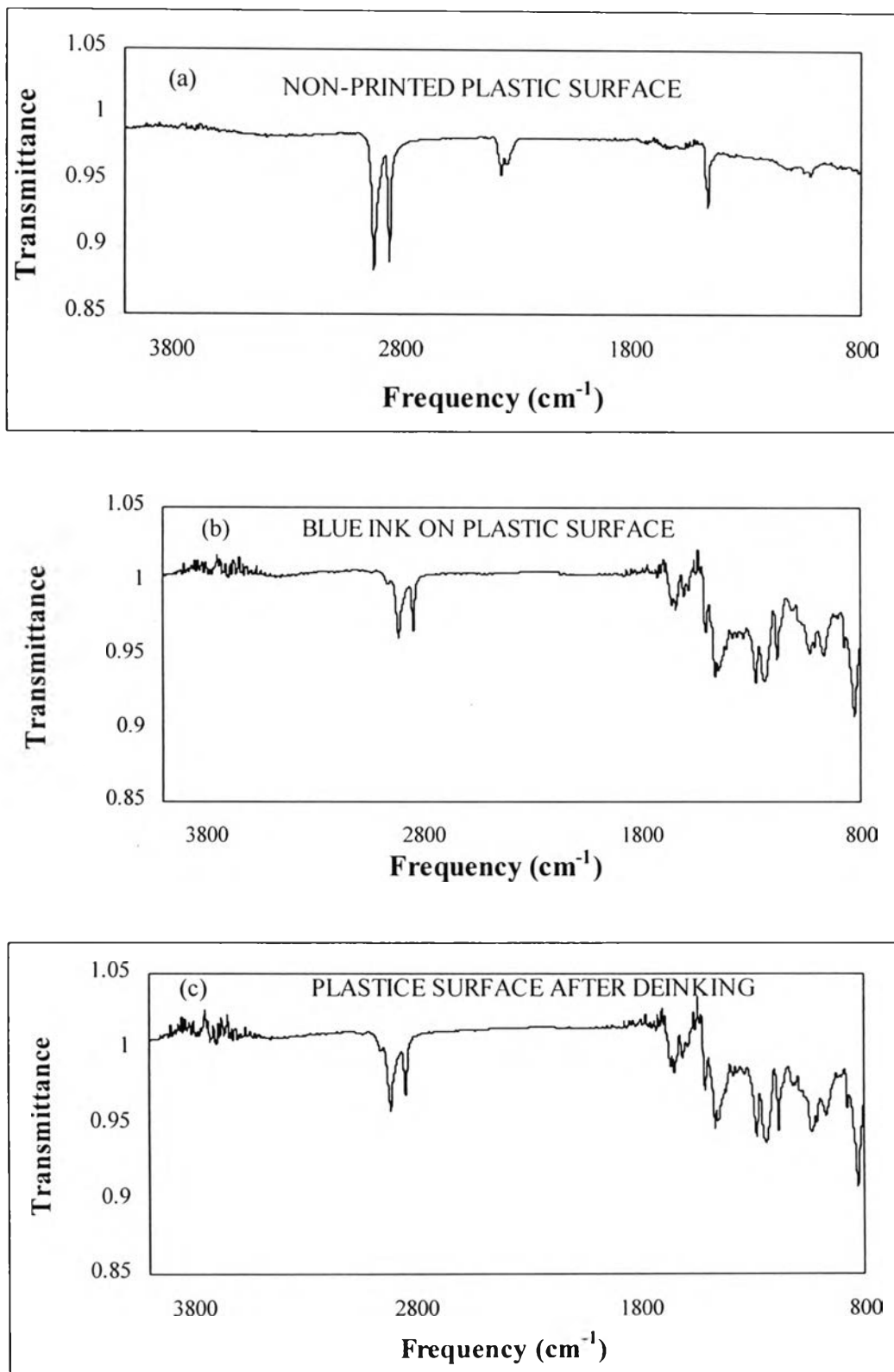


Figure 4.1 ATR-FTIR Spectra for (a) Non-printed Plastic, (b) Printed Plastic, and (c) Deinked Plastic with Surfactant-free Solution at pH 12 with 72 Hours Shaking Time and No Pre-soaking Time

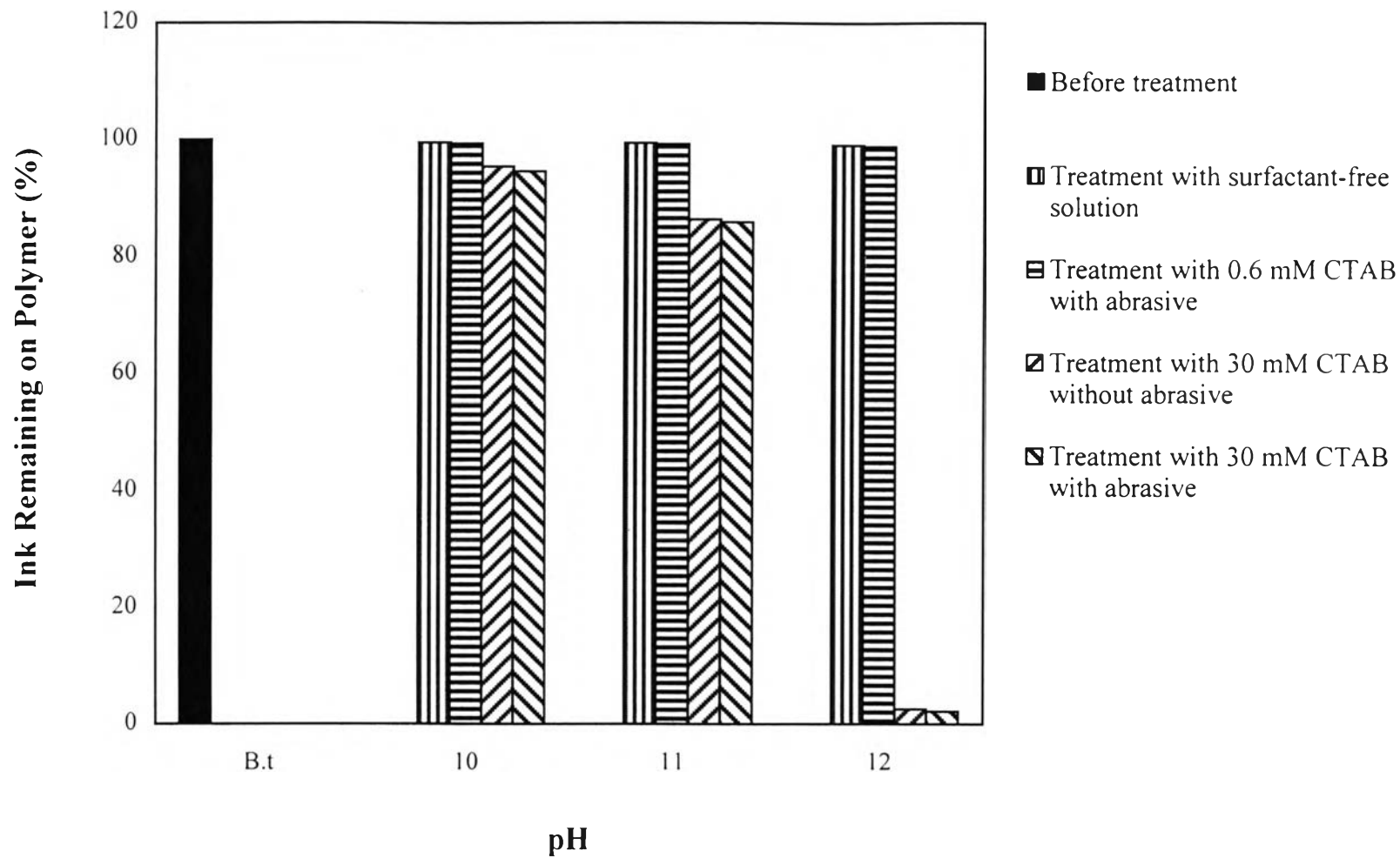


Figure 4.2 Comparison of the Residual ink on Plastic Surface Deinked Using Surfactant-free Solution and Using CTAB with 2 Hours Shaking Time and No Pre-soaking Time with or without Abrasive at Various pH

4.2 Effectiveness of Deinking with Cationic Surfactant

A number of deinking experiments were conducted with CTAB either above or below the CMC in solutions of pH ranging from 10 to 12 under various conditions. As shown in Figure 4.2, cationic CTAB at a concentration above CMC with 2 hours shaking time without pre-soaking removed almost all of the ink from the sample plastic surface with or without added abrasive. It is proposed that in this process, the inks become negatively charged under basic conditions. The electrical forces will probably help the cationic surfactant molecule adsorb onto the ink and polymer surfaces when the ink and surfactants are oppositely charged. The adsorption of a cationic surfactant onto a negatively charged surface reduces the charge on the surface and may even reverse it to a positive charge (if sufficient cations are adsorbed) (Rosen, 1989). The resulting dispersion of ink from the plastic surface was probably due to the electrostatic and steric repulsion of surfactant molecules between the ink and the plastic surface.

By comparing the resulting spectra (Figure 4.3 and Figure 4.4) from the analysis, it can be seen that the spectrum (c) of Figure 4.3 (the deinked sample) contacted with a 30 mM CTAB solution at pH 12 is very similar to the spectrum (a) of the non-printed plastic sample indicating that most of the ink had been removed from the deinked plastic surface. In contrast, spectrum (c) in Figure 4.4, for 30 mM CTAB solution at pH 11, looks very similar to spectrum (b) of the printed plastic indicating that much of the ink remained on the plastic surface at pH 11. As shown in Figures 4.3 and 4.4, the use of CTAB above CMC at pH 12 removed almost all of the ink from the plastic surface while it removed very little ink at pH 11 and 10 under the same conditions. The experimental results show that pH was very critical for complete deinking. IR studies also indicated that all of the ink binder contained ester groups. The intense C=O stretching band of saturated aliphatic

ester is in the frequency range of $1750 - 1735 \text{ cm}^{-1}$ (Silverstein *et al.*, 1991). This is in good agreement with the resulting stretching band occurred in the ATR-FTIR spectra (b) of blue ink on plastic surface. Sodium hydroxide could also help to break up the ink binder by hydrolysing ester groups especially at pH 12. For CTAB below CMC, no significant deinking occurred at all pH levels.



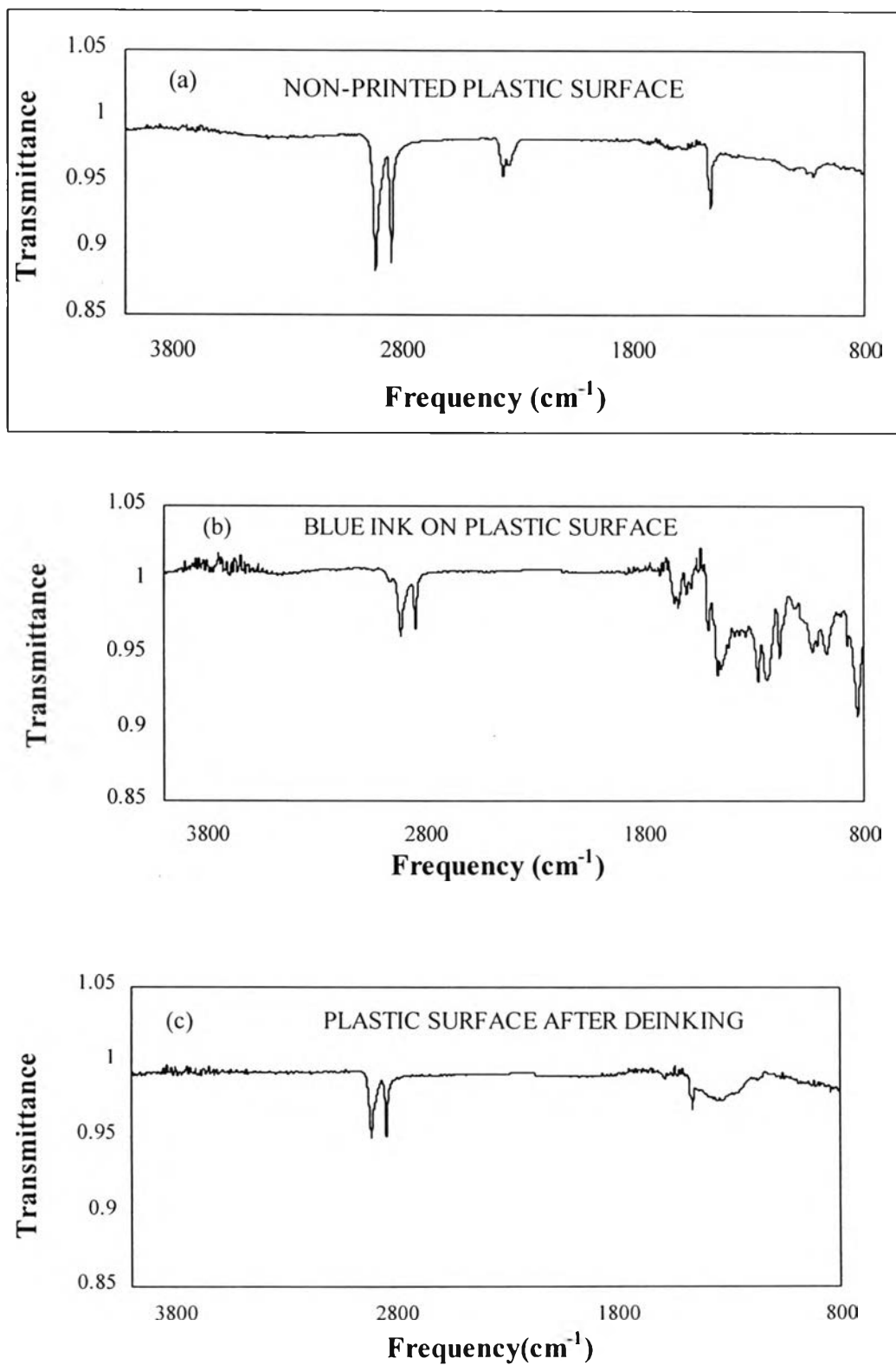


Figure 4.3 ATR-FTIR Spectra for (a) Non-printed Plastic, (b) Printed Plastic, and (c) Deinked Plastic with CTAB at pH 12 with 2 Hours Shaking Time and No Pre-soaking Time

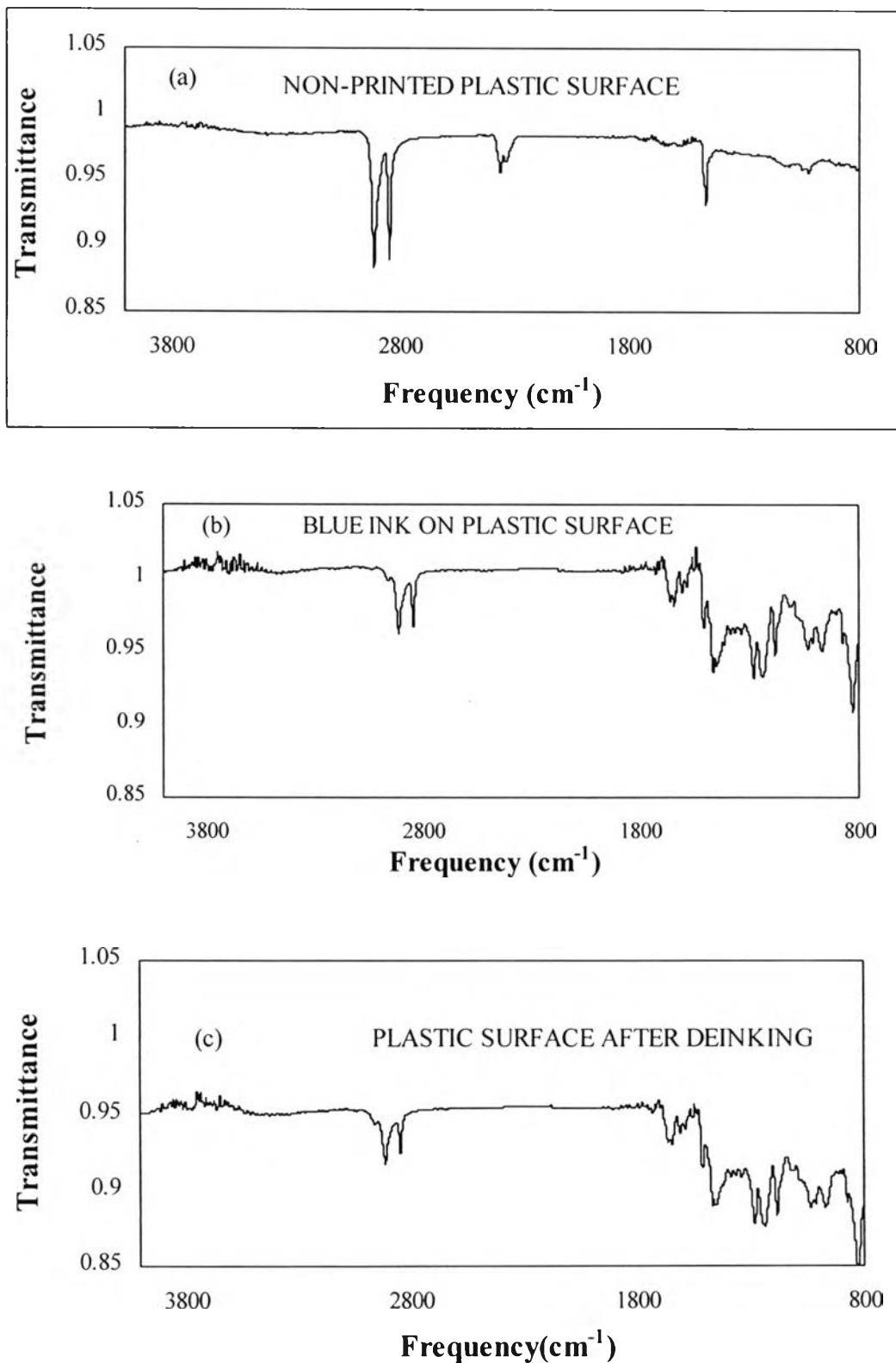


Figure 4.4 ATR-FTIR Spectra for (a) Non-printed Plastic, (b) Printed Plastic, and (c) Deinked Plastic with CTAB at pH 11 with 2 Hours Shaking Time and No Pre-soaking Time

To study the effect of pre-soaking time, some experiments were conducted with 30 mM CTAB solution at pH 12 at various shaking times with and without pre-soaking. A representative plastic sample was soaked in 30 mM CTAB solution for about 4 hours at room temperature and the effect of soaking time was determined. In Figure 4.5, the results demonstrated that there was no ink at all on the polymer surface after 4 hours of pre-soaking without shaking in a water bath. At the same time, another plastic sample was put in CTAB solution and shaken for about 1 hour without pre-soaking prior to being placed in the water shaking bath. The results show that the deinking experiment with only 1 hour shaking time without pre-soaking removed 50 % of the ink from the plastic surface whereas deinking with only 4 hours pre-soaking time without shaking of the samples removed almost all of the ink from the polymer surface. This suggests that soaking prior to shaking is necessary to remove all of the ink from the plastic surface. However, from the previous experiments, deinking with 2 hours shaking time without pre-soaking removed all ink from the plastic surface indicating that the degree of deinking significantly increased with shaking time.

Several experiments were performed to study the effect of shaking time on deinking of plastic containers with 30 mM CTAB (above CMC) at pHs of 10, 11, and 12. The shaking time was varied from 15 to 60 minutes following a 2 hours pre-soaking time. In Figure 4.6, the experimental results show that the degree of deinking significantly increases with shaking time.

From the data obtained in these experiments, the addition of abrasive was not found to be necessary since CTAB was able to detach the ink from the polymer surface by itself probably due to electrostatic and steric repulsion forces of surfactant molecules between the ink and polymer surfaces. Cationic surfactant CTAB performed the best for removing the ink from the plastic surface.

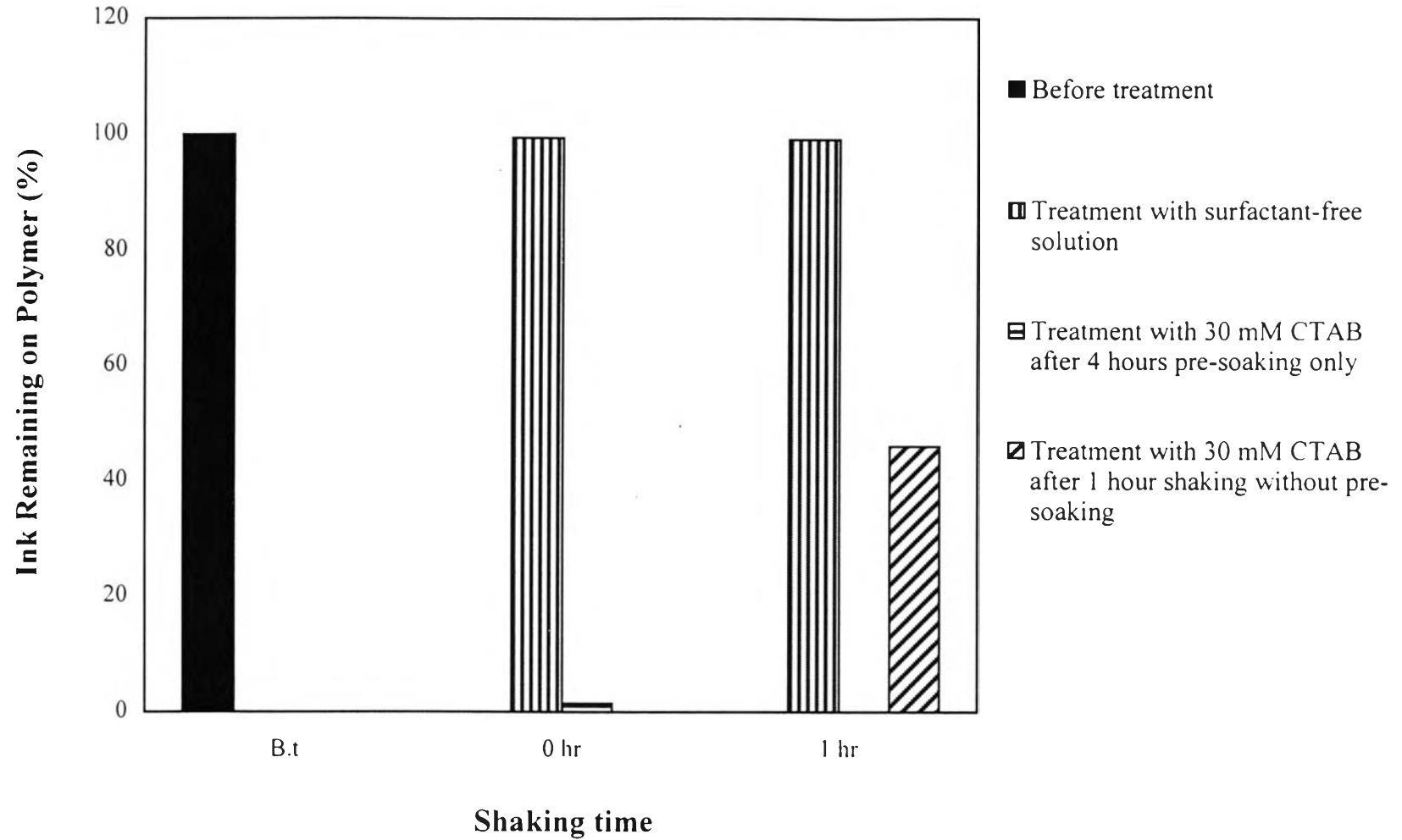


Figure 4.5 Comparison of the Residual Ink on Plastic Surface Deinked with CTAB with and without Pre-soaking at Different Shaking Times

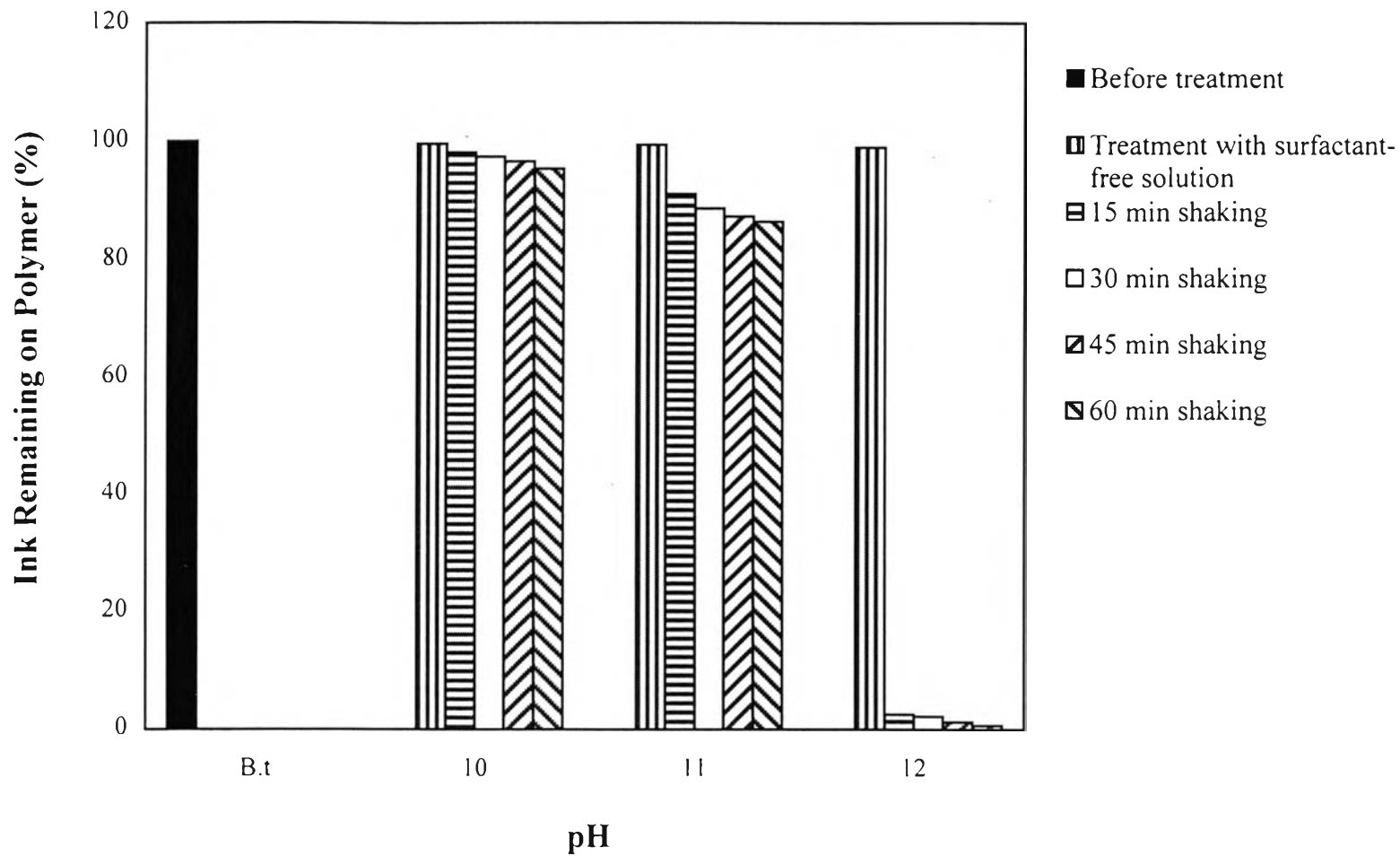


Figure 4.6 Comparison of the Residual Ink on Plastic Surface Deinked with 30 mM CTAB with 2 Hours Pre-soaking Time at Various pH and Shaking Times

4.3 Effectiveness of Deinking with Anionic Surfactant

Plastic samples were treated with 35 mM SDS at pHs of 10, 11 and 12 and shaken for 2 hours. As shown in Figure 4.7, there was no significant ink removal from the plastic surface at all pH levels studied. It is supposed that in this process, the weak adsorption of anionic surfactants onto the ink and polymer surfaces might have occurred as the electrostatic repulsion forces between the head group of the surfactant molecule and the negatively charged ink could decrease anionic surfactant molecule adsorption onto the ink. The insufficient adsorption of surfactants might cause poor wetting and water is not able to wet both the ink and polymer surfaces, resulting in the poor deinking effect. It was found that much of the ink still remained on the polymer surface after deinking with anionic SDS even at high pH levels. In contrast to CTAB, anionic SDS was the least effective surfactant for deinking of plastic containers under various conditions.

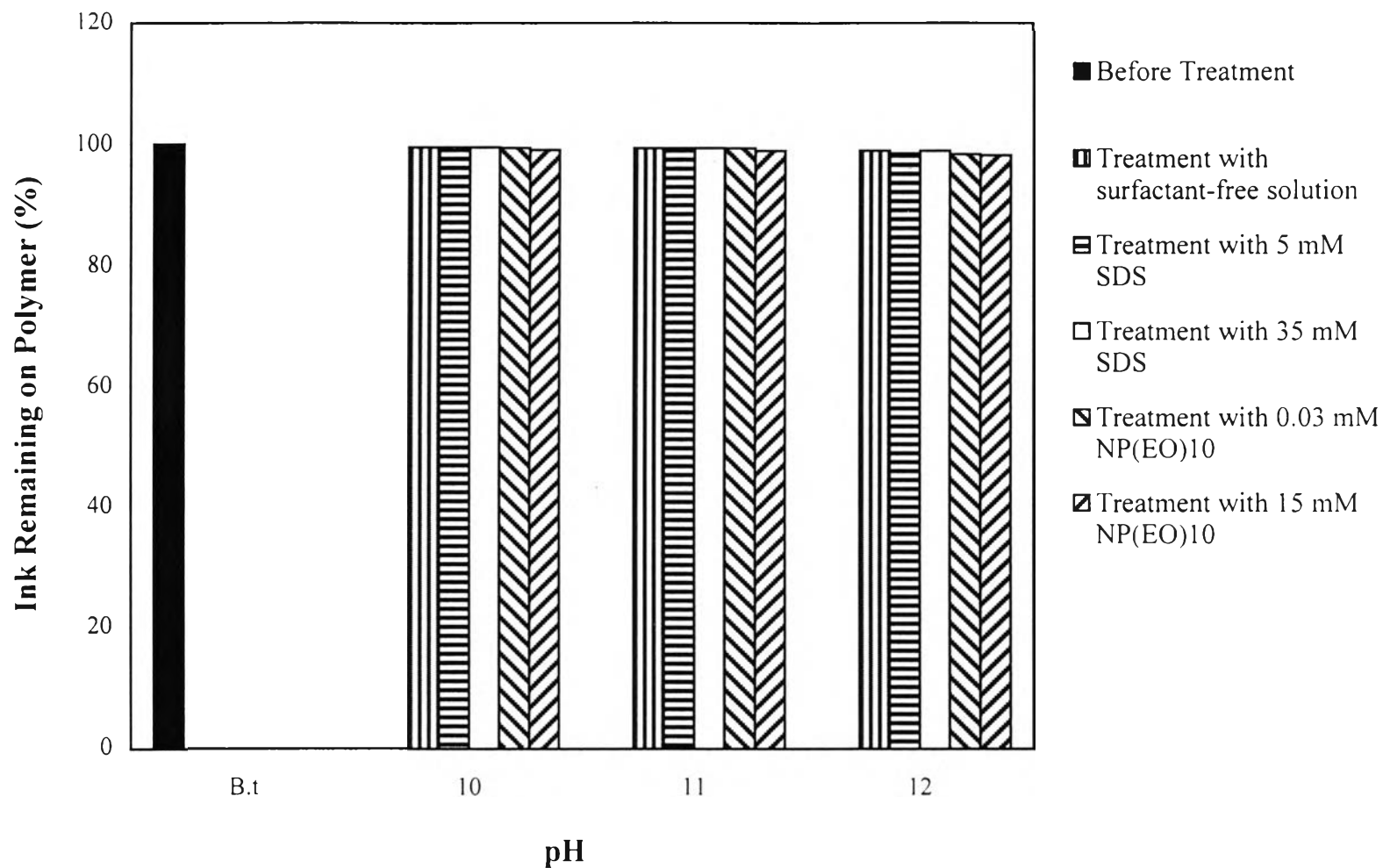


Figure 4.7 Comparison of the Residual Ink on Plastic Surface after Deinking with SDS or NP(EO)₁₀ with 2 Hours Pre-soaking Time Following 2 Hours Shaking Time at Various pH Levels

4.4 Effectiveness of Deinking with Nonionic Surfactant

The effect of nonionic surfactant NP(EO)₁₀ on deinking of plastic containers was investigated under various conditions and the degree of deinking observed. As shown in Figure 4.7, no detectable deinking occurred with nonionic surfactant below the CMC. Plastic samples were soaked in 15 mM NP(EO)₁₀ surfactant solution for 48 hours and then shaken for about 2 hours with or without added abrasive at room temperature. As shown in Figure 4.8, all of the ink from the polymer surface has been removed with the use of NP(EO)₁₀ above CMC after 48 hours pre-soaking and 2 hours shaking time at pH 12. Long soaking times were necessary for ink removal by nonionic surfactant NP(EO)₁₀. This behavior indicated that nonionic surfactant does not adsorb strongly onto charged surfaces probably due to the lack of electrical charges. Adsorption of nonionic surfactants onto the ink and polymer surfaces may be occurred gradually by hydrophobic bonding and abrasive may be needed to detach the loosened ink from the plastic surface. The mechanical action with abrasive increases the dispersion of ink in the surfactant solution (Gecol, 1998). There was no significant deinking using NP(EO)₁₀ at pH 10 and 11. The experimental data and results are presented in the Appendix.

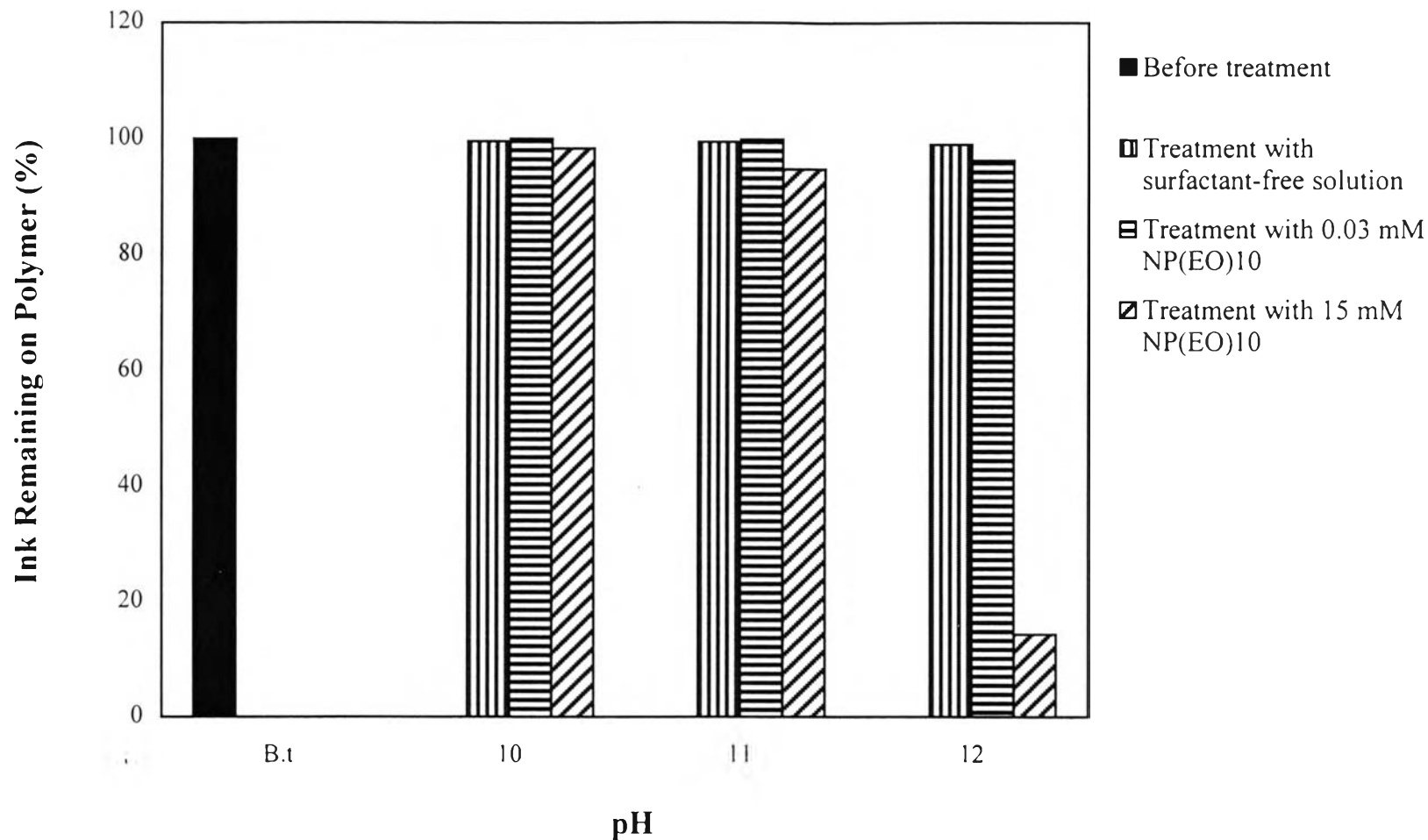


Figure 4.8 Comparison of the Residual Ink on Plastic Surface Deinked with NP(EO)₁₀ after 48 Hours Pre-soaking Time and 2 Hours Shaking Time at Various pH Levels