Treatment of Wastewater Contaminated with Water-Based Varnish and Glue Using Wasted Chemical and Materials in Coating/Lamination Plant

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Abstract
Vanish coating or film lamination is usually applied to protect the surface and add the value of printed products. Water-based coatings and water-based glues have become popular because of their environmental friendly and non-harmful properties. However, they caused wastewater from machine washing to be treated before discharge. The objectives of this research were to survey the sources of effluent in a coating/lamination plant and to find the proper technique of wastewater treatment. The effluent contaminated with water-based varnish and glue were mixed to determine the results of coagulation/flocculation using the wasted coagulant and materials. The results showed that 50 L of wastewater could be treated by adding 250 mL of wasted ferric chloride solution and stirring for 2 minute before leaving for sedimentation. The sludge was separated by filtering with the wasted mesh cloth and dried by sun. The residual color of water was further removed through the adsorption column packing with the granular activated carbon. The water qualities were detected for chemical oxygen demand (COD), total dissolved solids (TDS), suspended solids (SS) and pH value. After coagulation process, COD, TDS and SS values were reduced from 58,902, 30,424 and 772 mg/L to 7,384, 3,192 and 54 mg/L, respectively. After adsorption process, COD, TDS and SS values were further reduced to 23, 597.3 and 6.6 mg/L, respectively. The pH value was decreased from 7.6 to 5 by coagulation but it was increased to 7.13 after adsorption. The qualities of treated water were acceptable under standard criterion of Thai industrial effluent.

Keywords: Adsorption/ Coagulation/ Wastewater/ Water-based glue/ Water-based vanish

Introduction

Varnish coating on fiber materials can provide adequate protection from water vapor diffusion for a certain period of time and add the value of printed products. Water-based coating (dispersion varnish) are more prone to penetrate fibrous substrates such as paper, cardboard or corrugated board. The aqueous coating which is polymer dispersed in water dry physically by absorption into the absorbent substrates and evaporation of water through hot air and infrared to form the film over the surface. Water-based coatings have become popular in the printing industry especially for food, healthy and pharmaceutical packaging due to environmentally friendly, non-toxic and odorless (Thomas, 2013). In addition, absolute protection can be achieved by using film-laminated materials by overlay a layer of plastic film on substrate by the application of adhesives and pressure to improves strength, stability, gloss, matt and water/moisture resistance. The water-based glue is also usually applied in wet lamination to bond the plastic layer over the fibrous substrates. The inner lamination of the paper packaging also improve barrier or permeation properties to preserve the consumer products. Although the water-based varnish or glue containing disperse polymers and other water soluble additives are non-harmful and safety, it may cause high volume of wastewater due to the machine cleaning/washing with water after coating/lamination process.

The effluents contaminating with either varnishes or glues are much turbidity with high level of Chemical Oxygen Demand (COD), which must be removed before being discharged to impact the environment and ecology of stream. Coagulation-Flocculation is a common process to treat industrial wastewater in order to remove suspended particles from water. Most solids suspended in wastewater generally possess a negative charge; they consequently repel each other to prevent agglomerating. Many studies showed that the contaminant particles were removed from wastewater by mean of coagulation process using cationic coagulants such as ferrous sulfate, ferric chloride, alum, PAC, lime and polyelectrolyte (Asilian et al, 2006). The usage of commercial coagulants will increase cost of wastewater treatment process in many plants. In this study, the low-cost wastewater treatment was determined by utilizing the wasted materials in a coating/lamination plant which will be a good solution to manage their waste and wastewater. In the coating/lamination plant, there are many special effect coatings such as texture coating and spot coating. For texture coating, the embossing metal plate was made by chemical etching with ferric chloride acidic solution which might be reused as a low-cost coagulant for wastewater treatment. The treated water could be separated from the sludge by filtration using mesh cloth which was the wasted from making the screen plate used for spot coating. The residual color in water could be further removed by the adsorption process using the granular activated carbon (GAC) as economic adsorbent (Islam, A. 2013). The objective was to find the proper low-cost technique for wastewater treatment of the coating/lamination plants by utilizing their wasted materials.

Experimental

Survey of wastewater and collection of sample for coagulation batch test

The volume of wastewater was consider every day in 3 weeks and compared between 2 sources of effluent; coating machine washing (A) and lamination machine washing (B). The samples of effluent A containing water-based varnish and effluent B containing water-based glue in 1 L a week was then collected for coagulation batch test. Three types of wastewater contaminated with varnish, glue and mixture of varnish and glue were added with 1.2% (v/v) of ferric chloride solution and stirred for 2 minutes before leaving overnight. The efficiency of coagulation, flocculation and sedimentation of the samples were observed and compared.

Determination of effluent mixing ratio and coagulant dose in batch test

The optimum ratio of effluent mixing was also studied from 3 mixing ratio in volume of effluent A and B at 50:50, 70:30 and 80:20, respectively. Three lots of different wastewater samples collected from each 3 weeks were studied for the coagulation batch test using 1.2% (v/v) of ferric chloride solution. The sludge from sedimentation was separated by filtering with mesh cloth No. 200 or 75 μm openings. The pH values of wastewater and treated water, the reaction change, the settling time and the amount of sludge were analyzed. The wastewater mixed from effluent A and effluent B with an optimum ratio was then further studied using various dose of ferric chloride solution; 0.5%, 1%, 1.5%, 2% and 2.5% (v/v) respectively.

Designation of real large-scale wastewater treatment system

The coagulation/flocculation tank was designed using corrosion resistant stainless steel with the inner volume of 60 L. The radial impeller was used as agitator for mixing the coagulant dispersed throughout the water quickly. The cone-shape bottom also performs as a settling tank for sludge leaving by gravity. The sludge was discharged from the tank outlet and the treated water at upper level was flown to the adsorption column of granular activated carbon (GAC) with the inner volume of 100 L. The GAC was also used for air adsorption filter to separate gaseous harmful substances and odor in the plant. The mixture of 50 L wastewater from 2 sources was agitated for 5 minutes before adding with optimum dosage of ferric chloride solution and agitating for 2 minutes. After leaving overnight for settling, the sludge was separated by filtering, and the parameters of treated water were analyzed such as chemical oxygen demand (COD), total dissolved solids (TDS), suspended solids (SS), pH value and color.

Results and Discussion

Sources and volume of effluents from the coating/lamination plant

The volumes of effluent from 2 sources; coating machine washing (A) and lamination machine washing (B) were compared before consideration of wastewater treatment. Figure 1 indicates that the volumes of effluent containing water-based varnishes (A) were much more than that of effluent containing water-based glue (B) in every weeks.

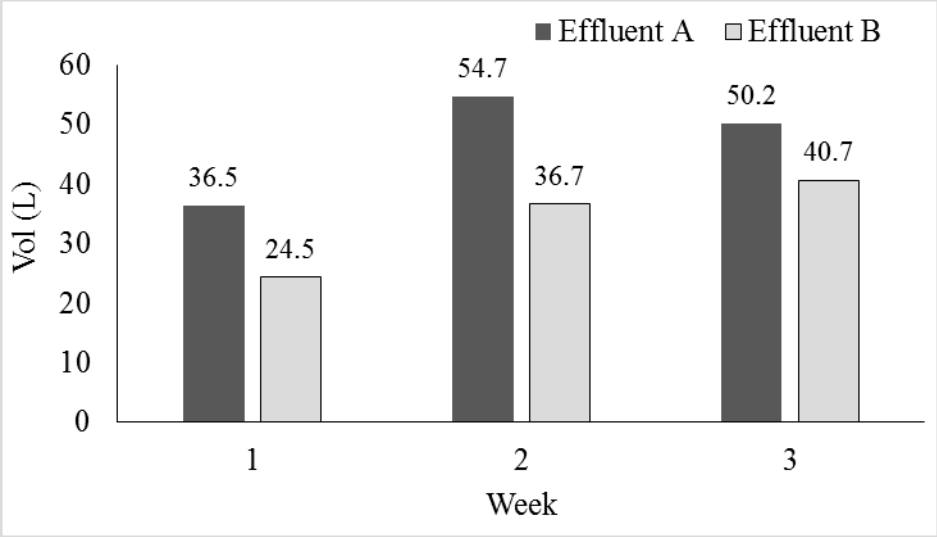


Figure 1: Volume of effluents from 2 sources in the plant for 3 weeks

Optimum wastewater mixing ratio and coagulant dose in batch test

The preliminary tested for coagulation using 1.2% (v/v) of ferric chloride solution showed that the effluent B and the effluent A+B had good flocculation. Their suspended particles rapidly formed to agglomerate into masses large enough to settle or be filtered from water while the flocculation of effluent A was not good enough, as shown in Figure 2.

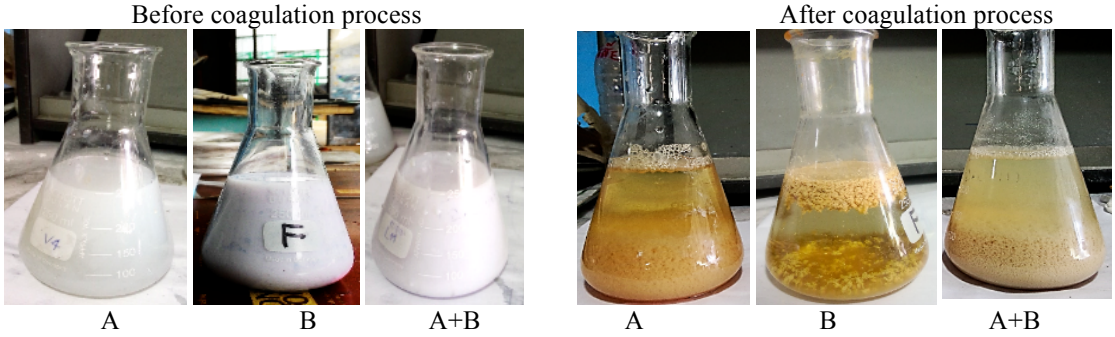


Figure 2: Effluent A, B and A+B before and after coagulation of wastewater

The glue contaminated in effluent B might reacted as an organic coagulant to enhance the agglomeration of particles, indicating that the wastewater from 2 sources should be mixed before treatment. Since the volume of effluent A was usually much more than effluent B and the volume of each week was not stable, the optimum ratio of effluent mixing was also studied. The results of various mixing ratio of effluents A and B in coagulation batch test were shown in Table 1.

Table 1: Coagulation/Flocculation results for different ratio (%) of effluent mixing.

Results	**A:B at 50:50**	**A:B at 70:30**	**A:B at 80:20**
Initial pH value	7	7	7
Color after coagulation	Yellowish	Dark Brownish	Dark Brownish

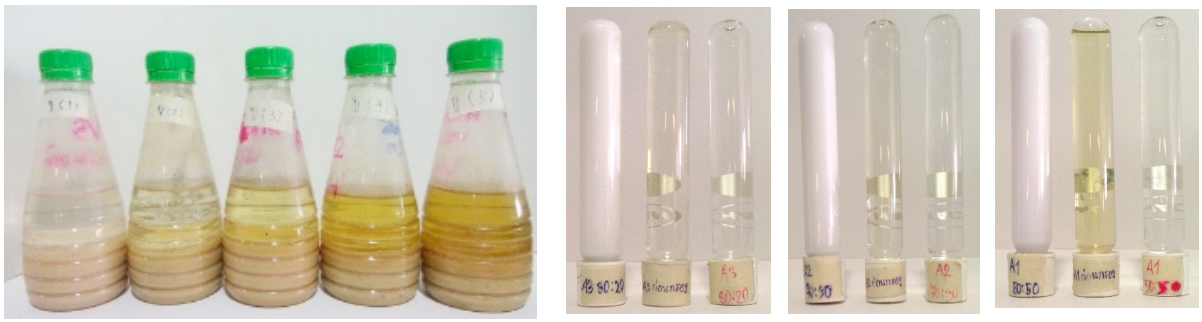
Final pH value	4-5	4-5	4-5
Flocculation	good	Not good	Not good
Settling time (min)	1-3	4-5	4-5
Sludge weight (g/L)	16.4 – 23.2	16.8 – 23.6	17.2 – 23.6

Table 1 shows that the optimum ratio (%) of wastewater mixing was 50:50 due to the good flocculation within shorter settling time. This means that 2 sources of effluent should be mixed together in the same volume. The amount of sludge was not significantly different and not much. It could be dried by sun and disposed as non-hazardous waste.

Table 2: Results of coagulation with different coagulant dose and adsorption with GAC.

Coagulant dose (% v/v)	Coagulation results		Adsorption results	
	Color of water	pH	Color of water	pH
0.5	clear	5	clear	6.5
1	slightly yellowish	3	clear	6
1.5	yellowish	3	clear	5
2	dark yellowish	2	N/A	N/A
2.5	dark yellowish	2	N/A	N/A

The optimum dose of ferric chloride solution was also determined in mixed effluent of A:B at 1:1. The results of different coagulant dose in Table 2 indicated that only 0.5% (v/v) of wasted ferric chloride solution was optimum for the coagulation of mixed effluent that contained varnish and glue. The flocculation was the best because the treated water was not yellowish as in Figure 3 (a) and the pH value was not too low in acidic range. After the water flowing through the GAC adsorption column, the pH was increased to be acceptable and the treated water was clear without color, as shown in Figure 3 (b).



(a) (b)

Figure 3: (a) Color of treated water after coagulation with different coagulant dose (b) Color of effluent, treated water after coagulation/filtering, and after adsorption with GAC

Real-scale wastewater treatment system

The mixture of 50 L wastewater containing mixed varnish and glue was treated with optimum dosage of 250 mL ferric chloride solution in the real-scale of wastewater

treatment system. The schematic diagram of wastewater treatment system in this plant is shown in Figure 4 and the results of wastewater treatment is shown in Table 3.

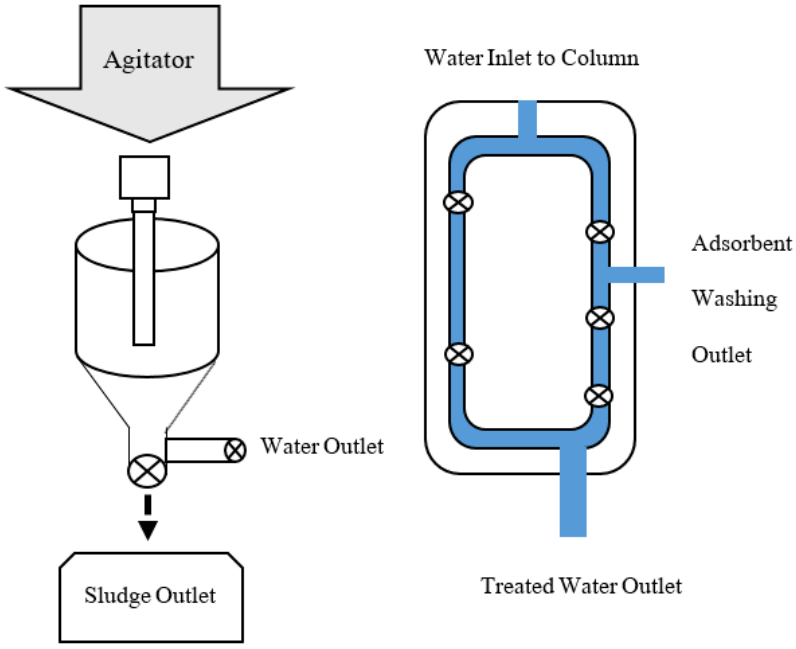


Figure 4: The schematic diagram of real-scale wastewater treatment system in the plant.

Table 3: Qualities of treated water from 3 samples of wastewater after coagulation and adsorption in real-scale treatment system.

Sample 1

Parameter	Wastewater	After coagulation & filtration	After adsorption with GAC	Standard criterion
COD (mg/L)	23,850	5,464	33	<120
SS (mg/L)	568	18	4	<50
TDS (mg/L)	31,644	3,386	546	<3,000
pH	7.4	5	7.54	5.5-9.0

Sample 2

Parameter	Wastewater	After coagulation & filtration	After adsorption with GAC	Standard criterion
COD (mg/L)	96,139	9,525	7	<120
SS (mg/L)	799	54	8	<50
TDS (mg/L)	36,644	3,370	652	<3,000
pH	8.2	5	6.83	5.5-9.0

Sample 3

Parameter	Wastewater	After coagulation & filtration	After adsorption with GAC	Standard criterion
COD (mg/L)	56,719	7,163	29	<120
SS (mg/L)	951	90	8	<50
TDS (mg/L)	22,984	2,820	594	<3,000
pH	7.3	5	7.02	5.5-9.0

The parameters of COD, SS, TDS values which indicated the contaminant in 3 samples of wastewater were removed by coagulation and adsorption, respectively, as shown in Table 3. The results showed that the treated water using 2 steps was acceptable with the parameter values under the standard criterion of industrial effluent. The removal efficiency of COD, SS and TDS in wastewater by coagulation and adsorption was analyzed as shown in Figure 5.

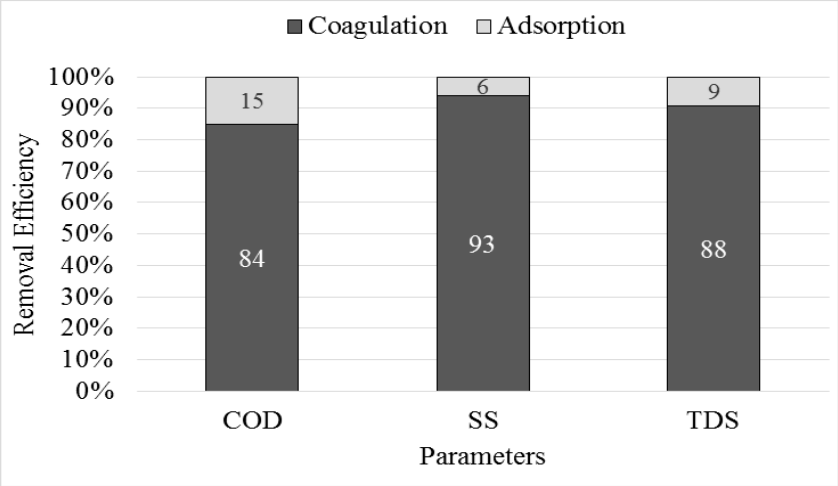


Figure 5: Removal efficiency of COD, SS and TDS in wastewater by coagulation and adsorption using wasted material in coating/lamination plant

Figure 5 indicated that the efficiency of COD, SS and TDS removal was very high by using the wasted ferric chloride solution as a coagulant. All parameters were further reduced to below the standard criterion by using the adsorption column of granular activated carbon. Therefore, the coagulation process using the acidic waste of the plant followed by the adsorption process using low cost activated carbon could be achieved with the removal efficiency at 97-99%. The sludge from coagulation process could be disposed by secure landfill and the spent GAC could be recycled or reused as the carbon-based fuel.

However, the volume of effluent A containing varnish from the coating machine washing was much more than that of effluent B containing glue from the lamination machine washing, as shown in Figure 1. If the effluent from 2 sources were mixed together at the ratio of 1:1, some volume of effluent A will be remained. The effluent A was then be tested for coagulation with wasted ferric chloride added with glue. It was found that 0.4% (v/v) of water-based glue could be used as co-flocculant to improve the flocculation efficiency of solid particles in effluent A. Therefore, the plant can use their wasted glue to reduce the cost of coagulation in treatment of the wastewater containing varnish coating.

Conclusions

The effluent from coating washing contained varnish and the effluent from lamination washing contained glue. Both effluents should be mixed together in the same volume before treatment by coagulation process using only 0.5% (v/v) of wasted ferric chloride solution which was optimum for the coagulation of effluent contained varnish and glue. The sludge could be separated from the water by filtering with

wasted mesh cloth. The yellowish color and the acidic pH of primary treated water could be removed by flowing through the GAC adsorption column. The removal efficiency of COD, SS and TDS was very high and the final treated water was acceptable with the parameter values under the standard criterion of Thai industrial effluent. The effluent containing only varnish could be treated by coagulation with wasted ferric chloride solution combined with 0.4% (v/v) of wasted water-based glue as co-flocculant to improve the flocculation efficiency.

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References

Asilian, H., Moradian fard, Sh., Rezaei, A., Mortazavi, B. and Khavanin, A. (2006). The removal of color and COD from wastewater containing water base color by coagulation process. *International Journal of Environmental Science and technology, 3 (2), 153-157.*

Thomas, G.P. (2013, Apr 30). Waterborne Coatings - Methods, Benefits and Applications. Retrieved from http://www.azom.com/article.aspx?ArticleID=8561

Islam, A. and Guha A.K. (2013). Removal of pH, TDS and Color from Textile Effluent by Using Coagulants and Aquatic/Non Aquatic Plants as Adsorbents, *Resources and Environment 2013, 3(5):* 101-114

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