Coagulation-Flocculation as Pretreatment for Rubber Glove Wastewater Reclamation System

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Abstract— **In this work, the rubber glove effluent was treated by using coagulation-flocculation method. Two different types of coagulant, i.e ferric chloride (FC) and polyaluminium chloride (PAC) were used in jar test. The wastewater was initially characterized in terms of pH, ammonia nitrogen (AN), chemical oxygen demand (COD), nitrate, total suspended solids (TSS), turbidity, total dissolved solids (TDS) and trace elements by using standard method. In jar test, COD and turbidity removal efficiency was used as performance indicator for the coagulation-flocculation process. Three parameters were carried out in jar test i.e pH (6-10), coagulants dosages (100-500 mg/L) and flocculants dosages (1-5 mg/L). For FC, the optimum conditions for coagulation-flocculation were pH 9, 400 mg/L coagulant dosage and 1 mg/L flocculants dosage with COD removal efficiency within 63 % to 88%. As for PAC, the optimum conditions achieved at pH 7.5, 400 mg/L coagulant dosage and 5 mg/L flocculants dosage with COD removal efficiency 38% to 98%. Overall, PAC shows greater turbidity removal efficiency up to 98% as compared to FC (94%). In conclusion, coagulant-flocculants could be used as an effective pre-treatment method to reduce the COD and turbidity level for rubber glove effluent.**

***Keywords*: Coagulation, chemical oxygen demand, Ferric Chloride, Polyaluminium Chloride, Turbidity.**

I. INTRODUCTION

In the manufacturing of rubber gloves, water is fundamental in the stage of dip and wash process. Latex wastewater contains high suspended solids (latex residues), high organic matter and nitrogen containing pollutants, high acidity and strong odors (Ashok et al., 2015). The increase of the rubber manufacturing industry in Malaysia can develop a horrendous environmental demolition (P.S. Yap et al., 2013). Wastewater released by industries posed a great hazard potential for environment since it involved many processes, which in turn, could lead to the contamination of freshwater and marine environments due to several of heavy metals being introduced into the soil and water sources (Abdul Fattah et al., 2013).

Wastewater from rubber gloves industry should be handling by treating the wastewater, hence, they can adhere to the environmental acts and regulations stated by Department of Environment (DOE) of Malaysia before the wastewater released into the river as it may contain hazardous contaminants that can harm humans (Sastry et al., 2000).

Coagulation and flocculation is a physical–chemical method that can be applied for the industrial wastewater treatment (Meng et al., 2018). It is proven that coagulation and flocculation (CF) are effective and easy methods for the treatment of wastewaters and widely applied in treating many types of wastewaters such as textiles waste, sanitary waste, pulp mill waste, palm oil mill waste and so on (Lee et al., 2014).

During the process, the addition of coagulants and flocculants in the wastewater will makes the dispersed or scattered fine solids collected together to produce big particles subsequently (Sharma et al, 2006). The removal mechanism of this process includes charge neutralization of negatively charged colloids by cationic hydrolysis products and incorporation of impurities in an amorphous hydroxide precipitate through flocculation (Abdul Fattah et al., 2013). The efficiency of coagulation-flocculation process depends on several factors such as type and dosage of coagulant/flocculants, pH, mixing speed and time, temperature and retention time.

Therefore, the objectives of this research are to characterize the wastewater from rubber glove manufacturing industry including the total suspended solid (TSS), total dissolves solid (TDS), pH, chemical oxygen demand (COD), ammonia nitrate (AN), nitrate and turbidity and apply coagulation flocculation process to treat the wastewater.

II. METHODOLOGY

A. Sample collection, storage and preservation

The wastewater was collected from a rubber glove factory located in Taiping, Perak. Once the sample was collected, the wastewater sample were kept in the cold storage at 1 to 4°C immediately to avoid and minimize the changes within the characteristic of the wastewater.

B. Characterization of rubber glove wastewater

In this study, the characterizations were done by using Hach Method. The parameters tested were ammonia nitrate (AN), chemical oxygen demand (COD), nitrate, total suspended solids (TSS), turbidity, total dissolved solids (TDS) and pH. The COD, AN and nitrate test was performed by colorimetric method, salicylate method, cadmium reduction method using Spectrophotometer HACH Model DR/2800. The pH meter was measured using Milwaukee MW 100 pH meter. TSS and TDS was measured using gravimetric method. The trace elements were measured using (Inductively Coupled Plasma (ICP).

C. *Jar Test*

Jar test was conducted in order to study the effect of pH, coagulant and flocculants dosages by using ferric chloride and PAC as the coagulants. Five 600 mL-beakers were filled with 400 mL of rubber glove wastewater and placed in the slots of a jar tester. The pH of samples was adjusted to the desirable values (according to the experimental design) by addition of diluted hydrochloric acid (HCl) or sodium hydroxide (NaOH) solution. Then, PAC and ferric chloride was added. The samples were rapidly stirred for 2 min at 100 rpm, and then slowly mixed for 30 min at 20 rpm. Then, the solution was kept undisturbed for 20 min for sedimentation. The clarified samples were collected from the top of the beakers and filtered using filter paper to remove any remaining sediment. The experiment was conducted by varying a few experimental parameters, which were coagulant dosage (100 – 500 mg/L), pH (6-10) and flocculants dosage (1-5 mg/L) in order to study their effect in flocculation and obtain the optimum condition for each parameter.

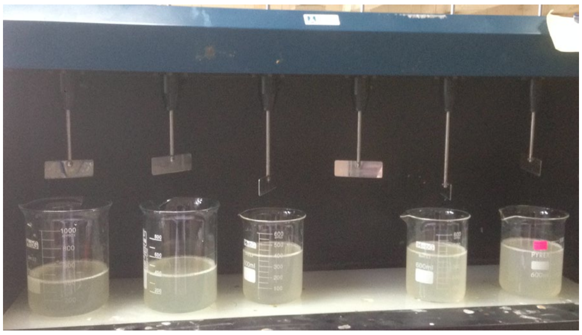

Figure 1: Jar test experimental set-up

COD removal efficiency (%) =

$$\left(\frac{COD_{initial} - COD_{final}}{COD_{initial}} \times 100\%\right)$$

Figure 2: DRB 200

Figure 3: DR 2800

D. *Analysis methods*

1. Chemical Oxygen Demand (COD)

The COD vials used in this analysis are in high range (0–1500mg/L). The colometric method was used to test COD. 2 ml of water sample was dropped into the COD vials and gently inverted to ensure the solutions are mix together. Then the vial was digested in Digital Reactor Block (DRB) 200 (as shown in Figure 2) for two hours at temperature of 150 °C (HACH, 2018). The sample was cooled down before analyzed using DR 2800 (as shown in Figure 3).

The percentage of COD removal efficiency, a formula was calculated using Equation 1:

2. Turbidity

Turbidity is cloudiness of a liquid from suspended solids that are invisible to the naked eye. 10 ml wastewater sample was filled into the sample cell and put into the cell holder for measurement using turbidity meter 2100Q (as shown in Figure 4).

The percentage of turbidity removal efficiency, a formula was calculated using Equation 2:

Turbidity removal efficiency (%) =

$$\left(\frac{Turbidity_{initial} - Turbidity_{final}}{Turbidity_{initial}} \times 100\%\right)$$

Figure 4: Turbidity meter 2100Q

III. RESULTS AND DISCUSSION

Table below shows the characteristics of the wastewater from manufacturing of rubber glove. The characteristics of the rubber glove wastewater were summarized and compared with Schedule B standards of the Sewage and Industrial Effluents Regulations under Environmental Quality and Act (1974) in Table 1.

Table 1: Characterization of rubber glove wastewater

Parameter	Value	Mean Value	Standard
pH	4.35-6.95	5.5	5.5-9.0
COD (mg/L)	1018-1636	1302.8	100
Total Suspended Solid (mg/L)	110-365	238	100
Total Dissolved Solid (mg/L)	1154-6020	2628	-
Turbidity (NTU)	189-247	227.6	0.1-5.0
Ammonia Nitrate (mg/L)	12-31	16.69	20
Nitrate (mg/L)	630-700	624	-

As in Table 1, COD, TSS and turbidity value were exceeded the standard due to the addition of nitric acid in the process of rubber glove. The feed wastewater consists of various mixture of complicated composition together with small quantity of uncoagulated latex, serum with significant amount of proteins, carbohydrates, sugars, lipids, and also includes inorganic and inorganic salts as well as wastewater produced by washing water from assorted processing stages

Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms. The COD test is often used as an alternate to BOD due to shorter length of testing time

ICP test was done in order to trace other elements such as aluminum, copper, chromium and others in the rubber glove wastewater. Table 2 shows the result of ICP test for characterization of rubber glove wastewater.

Table 2: Inductively Coupled Plasma (ICP) characterization of rubber glove wastewater

Element	Value	Mean Value
Silver	0.1308 - 0.2211	0.1759
Aluminium	1.3239 - 2.4999	1.7422
Boron	0.1785 - 0.1939	0.1862
Bismuth	0.1303 - 0.5346	0.2715
Barium	0.1679 - 0.2739	0.2209
Calcium	91.5016 - 402.904	292.309
Cadmium	0.1375 - 0.1819	0.1597
Cobalt	0.1254 - 0.1661	0.1457
Chromium	0.3050 - 0.3738	0.3381
Copper	0.1952 - 0.2430	0.2191
Iron	0.1252 - 0.1815	0.1534
Gallium	0.2740 - 0.3582	0.3161
Indium	0.1299 - 0.2443	0.1870
Potassium	371.063 - 517.636	459.564
Lithium	0.1993 - 0.2492	0.2242
Magnesium	6.95176 - 12.3484	10.474
Manganese	0.1132 - 0.1551	0.1342
Sodium	339.446 - 451.225	401.8233
Nickel	-	-
Lead	0.0114 - 0.2747	0.1648
Strontium	0.0229 - 0.3075	0.2020
Thallium	0.0188 - 0.0300	0.02440
Zinc	0.2370 - 1.5437	1.0406
Total	506.642 - 1369.202	1066.8467

1. Effects of pH

Figure 5 and 6 shows the COD and turbidity removal efficiency (%) versus pH for both coagulants. The optimum pH was to be found at pH 9 and pH 7.5 for ferric chloride and PAC, respectively. The highest COD and turbidity removal efficiency are in the range of 70.64% to 91.02% for ferric chloride. However, PAC has lower removal efficiency with only 37.56% to 48.91%.

For both coagulants, COD and turbidity removal efficiency for ferric chloride increased as the pH increased. However, PAC shows less impact on pH as expected, as it carries pre-polymerised sorts of aluminium. (A. Zouboulis et al., 2008)

In addition, there was a drastic drop for COD and turbidity removal efficiency achieved at pH 8. This poor performance was due to the phenomenon of excess polymer is adsorbed on the colloidal surfaces and producing restabilized colloids. Thus, there have been no sites offered on the particle surfaces for the formation of interparticle bridges. The restabilized colloidal particles can become positively charged and cause the electrostatic repulsion among the suspended solids (Ariffin et al., 2013).

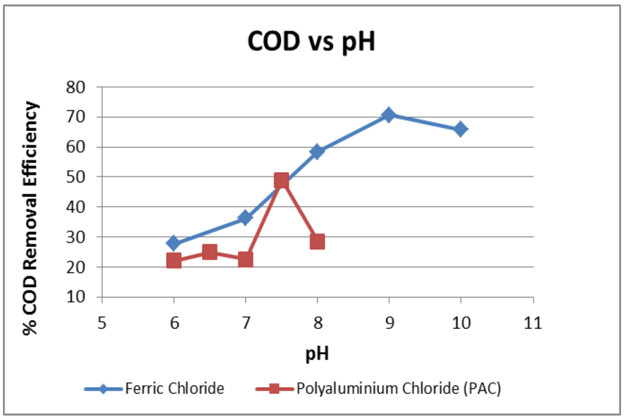

Figure 5: COD vs pH

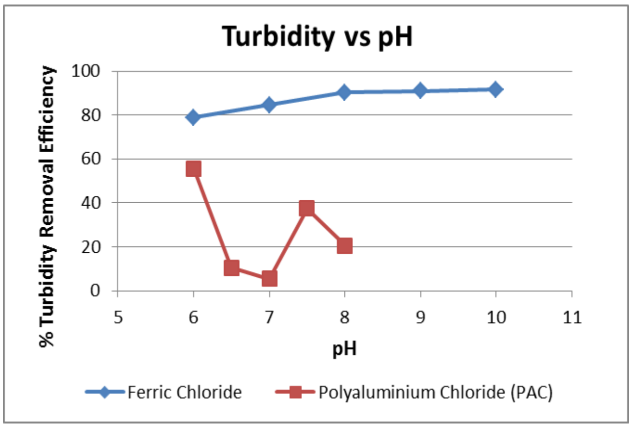

Figure 6: Turbidity vs pH

2. Effects of coagulant dosages

Dosage was one of the most important parameters to determine the optimum condition for the performance of Ferric Chloride and Polyaluminium Chloride (PAC) in coagulation and flocculation. Basically, insufficient dosage or overdosing would result in the poor performance in flocculation. Therefore, it was crucial to determine the optimum dosage in order to minimize the dosing cost and obtain the optimum performance in treatment (Ariffin et al., 2013).

The optimum coagulant dosages for both ferric chloride and PAC were found to be 400 mg/L. However, COD removal efficiency for ferric chloride is higher compared to PAC. COD removal efficiency and turbidity removal efficiency which has highest percentage reduction for about 88.6% meanwhile for turbidity it has 93.59% reduction.

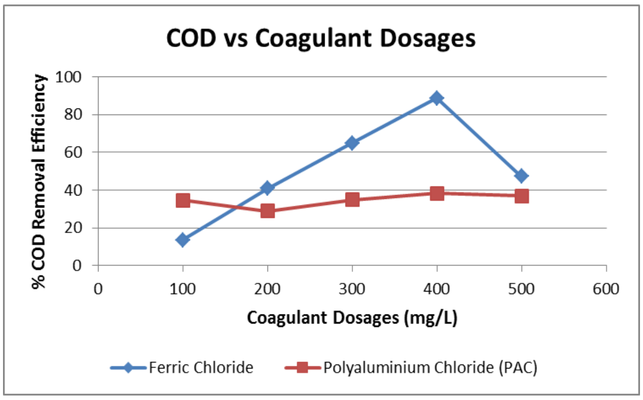

Figure 7: COD vs coagulant dosages

Based on Figure 8, there is increment in turbidity removal efficiency for both of the coagulants due to the addition of higher dosages of the coagulants.

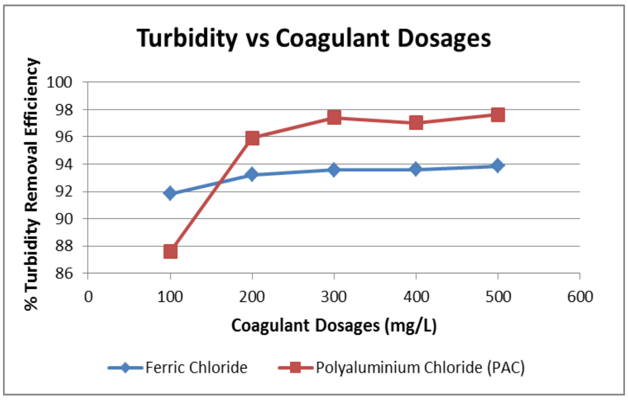

Figure 8: Turbidity vs coagulant dosages

3. Effects of flocculants dosages

The flocculants are used in this test in order to help the flocculation of suspended solids. The range of the polyacrylamide dosages in some studies state that it is good in range of 0.5 – 2.5 mg/L but in this research, the dosages for flocculants are 1, 2, 3, 4 and 5 mg/L and keeping other variables constant.

Based on Figure 9, it shows that PAC has higher turbidity and COD removal efficiency compared to ferric chloride. PAC has about 95% to 96% removal efficiency meanwhile ferric chloride could only maximize the reduction for only 55% to 63%. Based on studies by S.S. Wong et al, 2006, it is the quality most of the C-PAM studied considering that it is able to achieve 95% removal efficiency of turbidity at the dosage of 5 mg/L.

Figure 10 also shows the effective of PAC in turbidity reduction compared to ferric chloride. The optimum flocculants dosage for PAC is 5 mg/L meanwhile for the ferric chloride the optimum dosages is 1 mg/L.

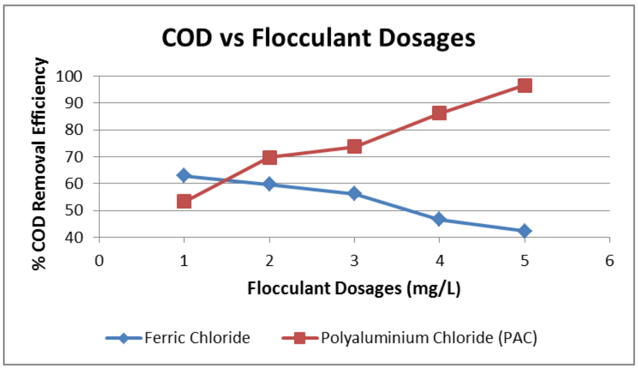

Figure 9: COD vs flocculants dosages

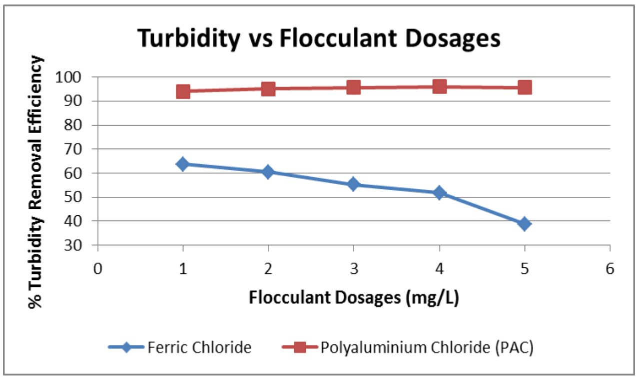

Figure 10: Turbidity vs flocculants dosages

IV. CONCLUSION

This research is conducted in order to achieve all the objectives stated above. Overall, PAC shows greater turbidity removal efficiency up to 98% as compared to FC (94%). Meanwhile, FC shows greater COD removal efficiency up to 88% compared to PAC. In conclusion, coagulant-flocculants could be used as an effective pre-treatment method to reduce the COD and turbidity level for rubber glove effluent.

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