Performance Study of Plant Based Coagulant to Treat Electroplating Wastewater

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Abstract— **The performance of dragon fruit foliage as a natural coagulant for treatment of electroplating wastewater was investigated by the jar test. The study also compared different dosages and pH values to determine the effectiveness of coagulation process. Dragon fruit foliage comes from the family Cactaceae which possess natural characteristics of the alum. Electroplating wastewater is one of the industrial effluents that contain high organic and inorganic substances as well as heavy metals that are harmful to the environment. Three main parameters; chemical oxygen demand (COD), suspended solid (SS) and Turbidity of wastewater were investigated in this study. From the experiment, the optimum percentage removals recorded for COD, SS and Turbidity were observed for effluent pH 10 and fixed dosage of 200 mg/L, at 89.6%, 76.9% and 89.7 % respectively. It is concluded that dragon fruit foliage works extremely efficient as natural coagulant to treat electroplating wastewater.**

Keywords*— *coagulant, dragon fruit foliage, electroplating wastewater

I. INTRODUCTION

Electroplating is the deposition of a plating layer of metal from an aqueous chemical bath with the aid of electricity (Raub, 2013). The components of electroplating process commonly are anode (+ve) and cathode (-ve) immersed inside a tank containing electrolyte. Electroplating is one of the electrochemical method used for depostion of metal onto metallic or other electrically conducting surface, or to increase thickness on layers previously formed by electroless deposition (Kanani, 2004). Through electrochemical reaction, a metallic coating is formed from an aqueous solution or a molten salt giving the surface treatment and finishing of metals and non-metals. According to Kanani (2004), electroplating process varies depending on the size and the geometry of the component to be plated, such as rack plating, mass plating, continuous plating and in-line plating. Electroplating industry offers many types of plating such as silver (Ag), copper (Cu), gold (Ag), tin (Sn), nickel (Ni), chrome (Cr), palladium (Pa), and anodizing. For each type of plating requires certain kind of chemicals for the process (Metal Finishing Industry, 2016).

Electroplating wastewater is one of the industrial effluents that contain heavy metals that can be harmful to the environment. Qin et. al (2001) reported that a significant amount of waste water is generated by the metal plating industry, in which everyday consumption of a small company with less than 100 employees is within 1000 cubic metre for rinsing purposes. Prasad and Abdullah (2010) state that industrial wastewater often contains considerable amount of heavy metals that are recognized as dangerous contaminants because of their high toxicity, accumulation and retention in the human body. The main way of contamination by these industries is the discharge of liquid effluents with relatively low, although harmful metal concentrations (up to some hundreds of mg/L) such as Cr, Ni, Zn, Cu and Cd which are usually the most abundant ones (Algarra et al., 2004). Electroplating effluent contains chromium in the form of Cr(VI). Cr(VI) has been classified by International Agency for Research on Cancer (IARC) as group 1 which states carcinogenic threat to human (Jabasingh et al., 2014). Zinc is essential for human growth; however, excessive level of zinc intake in the body can cause stomach cramps, skin irritation, vomitting, nausea and anemia (Pereira et. al, 2009).

There are various methods currently being used for electroplating wastewater treatment: chemical precipitation, coagulation/flocculation, adsorption, ion exchange and etc. In Singapore, conventional neutralization/precipitation is the most commonly used method for treating wastewater generated from metal plating industries before being discharged into the public sewer (Qin et al., 2001). Electrocoagulation method is an effective method at which the flocculating agent is generated by electro-oxidation of a sacrificial anode, usually made of iron or aluminium (Adhoum, 2003). Another method is ion exchange column which an attractive approach in which R-OH and R-H represent OH-type anionic and H-type cationic exchange resin, respectively (Xing et al., 2007). According to Hegazi (2013), rice husk and fly ash are the effective adsorbent in removing heavy metals from wastewater. Nanofiltration method is one of the new methods, i.e pressure-driven membrane process which has same separation characteristics between those reverse osmosis and ultrafiltration (Wei et al., 2013).

Coagulation/flocculation is generally used solid–liquid separation process for the removal of dissolved and suspended solids, organic matter and colloids present in industrial wastewater (Lee et al., 2014). Coagulation process usually occurs between different charges of coagulant and suspended solids in solution. As for example, most solids suspended in water are negatively charged particles and by addition of positive charged coagulant, both particles will stick together (Conradin et al., 2010).

Most common coagulant used in the treatment of water and industrial wastewater are alum ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$) and polyaluminium chloride (PAC), the chemical based coagulant. The problem arised about chemical coagulant is that it gives the harmful effects to human and the environment. Vijayaraghavan et al. (2011) stated that production of large volume of hazardous sludge resulted in high procurement cost. Nonetheless, a great alternative is that using plant based or natural coagulant to minize the aforesaid disadvantages.

There have been various studies done on plant-based coagulant which state that it is cost effective and producing biodegradable waste. Plant based coagulants are also known as point-of-use (POU) materials are used many years ago in the undeveloped communities. M. oleifera seeds after extraction have the potential to become new natural coagulant for palm oil mill effluent (POME) pretreatment. The results gave higher removal of suspended solids (95%) and COD reduction (52.2%) (Bhatia et al., 2007). Zhou et al (2008) use tannic acid, the natural polymer as the coagulant aid to develop an effective coagulation process. They concluded that tannin acid addition can accelerate the settling speed of the flocs. Chitosan can also flocculate particles into bigger flocs which become deposited (Lee et al., 2014). The properties of chitosan, including its cationic behavior (reactive amino and hydroxyl groups) and high molecular weight, may be used for both coagulation by charge neutralisation and flocculation by bridging mechanism (Li et al., 2013).

This study focuses on dragon fruit foliage as a potential plant based coagulant for the treatment of electroplating effluent. The foliage of dragon fruit tree is usually discarded as waste and such it has no value. It has been reported that, the existence of alum compound in the dragon fruit foliage was confirmed which dragon fruit foliages dominated the natural characteristics of the alum and moreover dragon fruit foliage was classified as one of the cactus family (Som et al., 2007). Work reported by Zhang et al., (2006), indicated that cactaceous opuntia was successfully reached 94% turbidity efficiency removal in water treatment. *Opuntia sp.* is a genus in the cactus family cactaceae. Dragon fruit foliage has been tested in removing methyl orange from aqueous solution; Haddadian et al. (2012) suggest that dragon fruit foliage is low-cost and environmental friendly adsorbent that may be used for the removal of MO from aqueous solutions.

This paper reports on the potential of dragon fruit foliage as natural coagulant for the removals of COD, SS and Turbidity from electroplating wastewater at preferable pH and dosage. The coagulation effectiveness was compared with Malaysian standard effluent discharge limit.

II. METHODOLOGY

A. Electroplating Wastewater

The wastewater sample is collected at Pandamaran, Klang, Selangor. The company is a plating service company which offers various kinds of plating such as silver, gold, tin, nickel, copper, chrome and anodizing. The samples are collected from a discharged pipe of untreated wastewater. Conditions of the effluent such as the pH, temperature, turbidity, total suspended solids and COD are determined before and after coagulation process.

B. Dragon Fruit Foliage

Dragon fruit foliage were collected at Sepang, Selangor. The collected foliage were removed torns, washed and dried. The foliage were then cut into small pieces and blended in dry blender. Then, the foliage juice was dried in the oven at 80 – 100 degree Celcius. The dried juice was then milled and sieved to a particle size of 0.45 to 1.25 mm.

C. Coagulation Jar Test

Coagulation experiments using a jar test were performed in laboratory with Bioblock flocculation that contain six-paddle rotor (24.5 mm x 63.5 mm) for 500 mL beakers and all tests were conducted at room temperature (Idris et. al, 2012). 500 mL of electroplating effluent was poured into each of 6 beakers. The desired amount of coagulant was added to the suspension and stirred at rapid mixing (120 rpm) for 1 minute. The mixing time and speed were recorded. Then, the speed of mixing was reduced to slow mixing (30 rpm) for 20 minutes to let the flocs particles suspended uniformly. The beakers were then withdrawn from the equipment, and settling of flocs was observed and recorded. The mixture was left for 1 hour, then the supernatant was collected to be used in the dertermination of COD, SS and turbidity using the standard method. The effect of pH was investigated in the range of 2 – 12 and the effect of dosage was investigated in the range from 200 mg/L – 700 mg/L. All analyses were recorded three times and pH of wastewater samples were controlled by adding 1.0 M NaOH or 1.0 M HCl.

D. Analytical Analysis

Turbidity test was performed using HACH Model 2100P turbiditimeter with measurement in nephlelometric turbidity unit (NTU). The collected supernatant was collected and filled into small bottle to determine the turbidity value. This turbiditimeter can measure turbidity of sample water from 0.001 to 1000 NTU in automatic range mode with automatic decimal point. the sample bottle was ensure to be cleaned because the measurement was based on light-transmitting properties of water. The tubidity removal percentage was calculated by using equation (1.1):

$$Turbidity\ (T) = \frac{T_{before} - T_{after}}{T_{before}} \times 100\% \qquad (1.1)$$

Suspended solid was determined by using HACH model DR 2000 Spectrophotometer using program .. The total suspended solid removal efficiency was calculated by using equation (1.2):

$$Total\ suspended\ solid\ (TSS) = \frac{TSS_{before} - TSS_{after}}{TSS_{before}} \times 100\% \qquad (1.2)$$

The COD test was performed according to HACH reactor digestion procedure, colorimetric determination method 8000 using DR 2000 HACH spectrophotometer with the COD range from 200 to 15, 000 mg/L. The low range (LR) COD digestion reagent vial was used with the electroplating effluent since its COD value was less than 200 mg/L. The COD reactor as shown in Figure 3.5 was first preheated at 150 °C followed by placing 2mL of wastewater sample into the vials using micrometre pipettes and deionized water was used to replace wastewater sample for blank test. The mixture was mixed and placed in the COD reactor for 2 hours. After 2 hours, the mixture was let to be cool for about 20 minutes. Colorimetric determination was then read at 435 COD HR modes. The recorded COD value was then calculated by using equation (1.3):

$$COD_{removal} = \frac{COD_{before} - COD_{after}}{COD_{before}}\ x\ 100\% \qquad (1.3)$$

III. RESULTS AND DISCUSSION

A. Characteristics of Raw Electroplating Effluent

The general characteristics of collected effluent sample are shown in Table 1. The effluent was collected at the general tank from the company's wastewater treatment plant (WWTP) prior to undergo treatment process. The general tank contains wastewater from the rinsing tank of all production lines in the electroplating company. From the table, it is clear that the wastewater has high total suspended solid (TSS) and turbidity values which were are 416 and 406 mg/L respectively, eventually both parameters contribute to the clarity of the effluent. The initial pH was 4.07 showed that the effluent was in acidic condition which may contain high concentration of hydrogen ions (the positive charged ions). The COD of the effluent was 193 mg/L which was within the range of discharge limit (according to Seventh Schedule; 80 – 200 mg/L) but Malaysia regulations is following the standard A discharge limit which is 80 mg/L, thus treatment is required before it can be discharged into the environment. Lastly, the tested temperature of raw effluent was 25 °C.

B. The Effect of Coagulant Dosage

Figure 1 shows the effect of different dosage of dragon fruit foliage at maximum removal of pH 4.07 on the removals of COD, SS and Turbidity by coagulation. In the dosage ranges 200 – 700 mg/L, the turbidity removal percentages show more than 75% removal is achieved. Research done by Zhang et al. (2006) is proven in which 94% turbidity removal is achieved when the wastewater is treated by the cactus as coagulant. The turbidity was removed efficiently at 200 mg/L coagulant dosage with 82% removal, whereas less than 70% suspended solid removal was obtained in the range dosage of 200 – 700 mg/L. As shown in figure 1, where dragon fruit foliage dosage increases, the SS removal efficiency is decreases. As Som et al. (2010) stated, the decrease in the suspended solid removal is because of the result of re-suspension of solids at certain concentrations and it depends on the pH of the effluent. However, the percentage of COD removal shows below 20% and eventually decreases when in the dosage ranges from 300 – 700 mg/L.

Table 1: Values of selected parameters of raw electroplating effluent

Parameters	Average value of raw electroplating effluent
Temperature, °C	25
pH	4.07
Chemical Oxygen Demand, mg/L	193
Total suspended solid, mg/L	416
Turbidity, NTU	406

C. *The Effect of pH on Coagulation Process*

Figure 2 shows the effect of electroplating effluent pH on coagulation effectiveness at coagulant dosage of 200 mg/L. The alteration of effluent pH in the range 2 – 12 seem to influence the percent removals of COD, SS and Turbidity. The optimum COD, SS and Turbidity removals observed at pH 10 which were found to be 89.6%, 76,9% and 89.7% respectively. These results are in agreement with those reported by Som et al. (2007), who showed that the optimum pH range of concentrated latex effluent for COD, SS and Turbidity removals was 10 when dragon fruit foliage was used a coagulant in coagulation process. At pH 12, SS and Turbidity show up the highest effiency removal which were observed to be 87.3% and 94.9% respectively. This perhaps the condition of solution in basic and acidic pH where the increased concentration of hydroxyl group (OH^-) (in this situation) boost up the chemical ionic interaction between coagulant and chemical species in effluent, thus enhance coagulation process.

The curve for foliage was found that it has two visible "peak" which at pH values 4 and 10. Findings from Idris et al. (2012), on concentrated latex effluent treatment with dragon fruit foliage as plant based coagulant indicate similar trend in which two "peak" pH values are 3 and 10. Interestingly, research from Aziz et al. (Cited in Idris et al., 2012) on color removal from landfill leachate using ferric sulphate, showed the two "peak" at pH values 4 and 12. This phenomenon denotes that it is not only present in this study but also observed in other coagulation research as well (Idris et al., 2012).

Figure 3 shows the effect of electroplating effluent pH on coagulation effectiveness at coagulant dosage of 300 mg/L. The optimum range of pH for COD, SS and Turbidity removals observed is at pH 10 which are found to be 13%, 81.5% and 84.3% respectively. Visibly seen at figure 3, COD percentage removal is below 15% as it is obvious that COD removal efficiency is depleted when tested using dosage coagulant of 300 mg/L as compared to the result on Figure 2. It may because of great amount of contaminant, such as organic matter, makes the metal solubility greater than that expected, mainly due to the chemical interactions between the metallic cations and organic matter (Heredia et al, 2009). Wastewater contains both oxidizable organic and inorganic compounds which directly and indirectly consume the available oxygen present in the ecosystem. (Moreno-Casillas et al, 2007). Therefore the increasing amount of dosage has increasing the contaminants in the wastewater where unnecessary amount of dosage in reducing the effectiveness of COD removal effiency.

The turbidity removal percentage at pH 4 for dosage 200 mg/L and 300 mg/L were observed at 73.1% and 71.7% respectively. This has proved the findings from Khodapanah et al. (2013), on potential of using bio-coagulants indigeneous to Malaysia for surface-water clarification, indicate that the coagulation activity of dragon fruit foliage is greatest at pH 4 with 78% removal efficiency in turbidity.

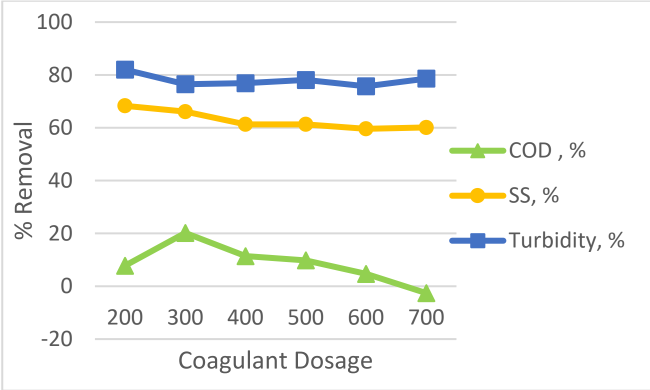

Fig 1: The effect of coagulant dosage on the removals of COD, SS and turbidity using dragon fruit foliage

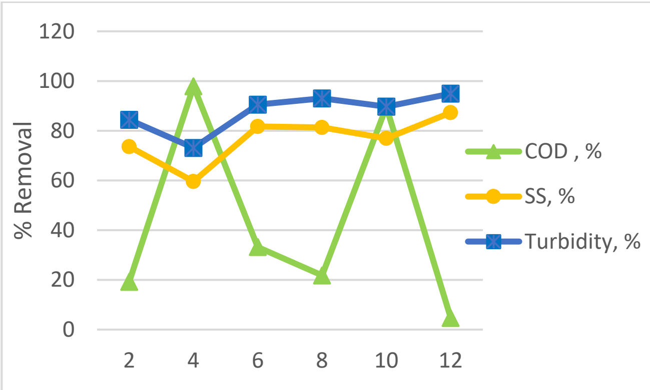

Fig 2: The effect of pH values on the removals of COD, SS and turbidity using coagulant dosage 200 mg/L

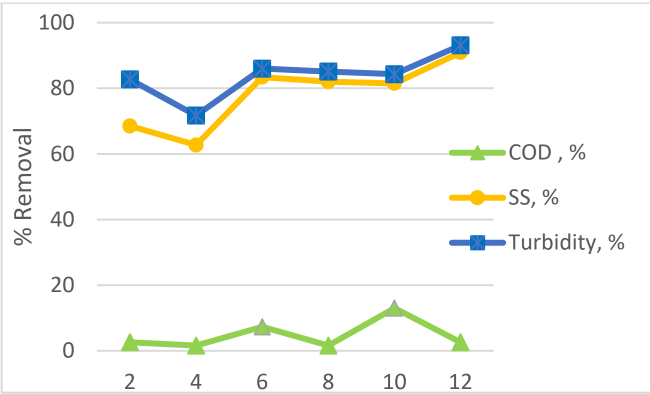

Fig 3: The effect of pH values on the removals of COD, SS and turbidity using coagulant dosage 300 mg/L

In the present work, it is recommended that the pH value of 10 with coagulant dosage of 200 mg/L is the best in terms of COD, SS and turbidity removals which are found to be around 89.6%, 76.9% and 89.7% respectively.

IV. Conclusion

This study shows that the dragon fruit foliage performance as natural coagulant for the treatment of electroplating wastewater is a successes. The experimental was to determine the percentage removal in terms of COD, SS and Turbidity as well as determining the right coagulant dosage and pH condition to achieve maximum percentage removal. It was found that dragon fruit foliage has the potential as natural coagulant for electroplating wastewater treatment. The optimum removal efficiencies of COD, SS and Turbidity for effluent pH 10 at 89.6%, 76.9% and 89.7 % respectively. For future study, it is suggested that the dragon fruit foliage powder is sieved into smaller siever size which less than 1.25 mm. The effectiveness of coagulant is compared with various dosage at optimum pH selected as to determine which coagulant dosage in the range 200 – 1000 mg/L give the highest removal efficiency in terms of COD, SS and Turbidity. Also, it is suggested to regulate pH between 5.5 – 9.0, as it is the standard permissible effluent discharge limit.

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