TREATMENT OF TEXTILE WASTEWATER USING *HIBISCUS ROSA-SINENSIS* (BUNGA RAYA) LEAF EXTRACT AS COAGULANT

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ABSTRACT

Treatment of textile wastewater is one of the largest problems faced by the textile manufacturers in Malaysia. This study was conducted to investigate the efficiency of *Hibiscus rosa-sinensis* or Bunga Raya leaf extract as coagulant and coagulant aid with poly-aluminium chloride (PACl) for the treatment of textile wastewater. Evaluation was based on the removal of chemical oxygen demand (COD), suspended solids (SS), color as well as the influence on zeta potential and particle size using standard jar test apparatus. The removal efficiency of PAC was rather efficient where 66.3% COD, 97.7% SS and 82.9% color was removed, respectively at optimum pH 7. Hibiscus leaf was not effective in terms of removal efficiency with low COD, SS and color removals of 10.9, 43 and 17.1%, respectively at pH 7. The optimum pH for hibiscus leaf was 6. However, when hibiscus leaf was applied as coagulant aid, the COD, SS and color removals were 77.8, 99.4 and 78.4%, respectively at pH 7, while the optimum pH was 8. When hibiscus was added as coagulant aid, the amount of PACl reduced to 3600 from 6480 mg/L. Nevertheless, the addition of hibiscus leaf influenced the zeta potential and increased the particle size of flocs.

Keywords. textile wastewater, Hibiscus rosa-sinensis, PACl, coagulant, COD.

1. INTRODUCTION

The composition of wastewater from dyeing and textile processes has daily and even hourly variations depending on the dyestuff, fabric and concentration of fixing compounds which are added [1]. Unfixed dye releases large doses of colour to the end of pipe effluents. Biological treatment processes are commonly used to treat textile effluents [2]; however, these processes are highly inefficient in removing colour which is visible at very low concentrations [1]. Textile plants produce extremely toxic effluent which is characterized by low biodegrabadility and high biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids (SS), pH, colour and slat contents. According to Wijetunga et al. [3], the nature of textile effluent is determined by the type of fabric, dye, technology and colour. Therefore, the composition of dye effluent varies with the type of textile produced.

Coagulation–flocculation is a relatively simple physico–chemical technique commonly used in water and wastewater treatment [4,5]. The removal mechanism involved in coagulation-flocculation process primarily consists of charge neutralization of negatively charged colloids by cationic hydrolysis products followed by incorporation of impurities in an amorphous hydroxide precipitate through flocculation [6]. Inorganic metal salts such as alum, ferrous sulfate, ferric chloride and ferric chloro-sulfate are generally used in coagulation–flocculation [5]. Among these inorganic coagulants, iron salts are often more efficient than aluminum ones (7). Recently, there has been a rise in the use of polymerized forms of metal coagulants such as poly-aluminum chloride (PACl) for water treatment in Europe, Japan and North America due to their reduced cost and wider availability [8]. PACl contains a range of pre-formed Al(III) hydrolysis species with superior quality and structure which are quite stable for further hydrolysis and more effective at charge neutralization which contributes to higher coagulation efficiency [9,10]. In comparison to alum, PACl is more effective at lower temperature and has a broader pH range. Besides that, the high charge density of PACl also leads to decrease in coagulant dosage and sludge production [10]. Introducing natural coagulant would be beneficial in terms of environment, cost effectiveness and economic sustainability. In addition, natural coagulants are biodegradable and not harmful to human health. A number of studies have been reported using natural polymers for the treatment of various types of wastewater [11-18].

The species of *Plantago psyllium*, *Tamarindus indica*, *Trigonella foenum-graecum*, *Moringa oleifera* and *Hibiscus esculentus* have shown promising results with respect to wastewater treatment [19]. Mishra et al. [20] studied the flocculation of textile wastewater by using *Plantago psyllium mucilage.* According to them, natural anionic polysaccharide of the species was found to be a very effective flocculant with more than 90 and 68% of SS and total dissolved solids (TDS), respectively. Another study looked at the flocculation behavior of *Tamarindus* mucilage for the removal of vat and direct dyes from textile effluent [21]. At optimum mucilage dosage of 10 and 15 mg/L, the removal obtained was 60% for golden yellow after 2 hrs and 25% for direct fast scarlet after 1 hr, respectively. Based on the successful application of natural coagulants in previous studies, other natural coagulants are required to be explored for their effectiveness in coagulation and flocculation process. *Hibiscus rosa-sinensis* leaf extract has been tested in leachate treatment and it has shown promising future. The need of exploring other natural coagulants is further stressed by the harmful effects of chemical coagulants such as alum. According to Martyn et al. [22], releasing alum into the environment might be catastrophic and it could cause Alzheimer's disease due to its carcinogenic properties.

Malaysia is a tropical country which is rich in various kinds of useful natural polymers such as tapioca, sago and roselle. The unlimited supply of these polymers has to be fully utilized in order to explore their potential of being used in the treatment of wastewater. A few natural coagulants such as powdered roistered grains of zea mays in Peru and sap of tuna cactus in Chile have been used since ancient times. The objective of this research was to extract the leaf of *Hibiscus rosa-sinensis* to be used as alternative coagulant aid and to measure the charge density. Further, the optimum dosage of PACl and *Hibiscus rosa-sinensis* as coagulants in removing COD, SS and colour from textile wastewater was determined. Moreover, the influence of *Hibiscus rosa-sinensis* as coagulant aid on the removal of COD, SS and colour was determined in addition to determining the zeta potential and flocs generated.

2. MATERIALS AND METHODS

2.1. Wastewater collection and characterization

A textile company in Prai, Penang was selected as case study site and untreated textile influent was collected for laboratory tests. The sampling was carried out by using 25 L plastic containers with sealed caps. Textile influent was stored in a cold room at 4°C to minimize biological and chemical reactions. The samples were then analyzed for COD, SS, colour and zeta potential. Characteristics of wastewater are given in Table 1. All analytical procedures were performed using standard method of water and wastewater [23]. pH was measured using a portable pH meter (Hach, sens ion 1, USA). COD was determined using Colorimetric Method (5220-D). SS were determined by using Method No. 2540D. Color measurements were reported as true colour (filtered using 0.45 µm filter paper) assayed at 455 nm using DR 2000 HACH spectrophotometer. Method No. 2120C reports color in Platinum–cobalt (PtCo), the unit of colour being produced by 1 mg platinum/L in the form of the chloroplatinate ion. The effect of filtration on colour removal was corrected by means of a control sample.

Table 1. Characteristics of textile wastewater

Parameter	Textile Wastewater	
	Sample 1	*Sample 2*
pH	12.12	10.32
COD	1440 mg/L	1250 mg/L
SS	128 mg/L	167 mg/L
Colour	1400 PtCo	2310 PtCo
Zeta Potential	-47.34 mV	-44.8mV

2.2. Coagulation/flocculation

Coagulation experiments were performed using jar test equipment (Jar Tester model JLT, Velp, Scientifica, Italy) comprising six paddles rotors (25-75 mm) equipped with 6 beakers of 1 L each with variable speed mixer (0-350 rpm). Chemical coagulant (PACl) was used as a comparison to natural coagulant, (*Hibiscus rosa-sinensis leaf* mucilage. In addition, *Hibiscus rosa-sinensis leaf* mucilage was used as coagulant aid to PACl in treating textile wastewater. Textile wastewater was moved from the cold room and left at room temperature for around 2 hrs at about 25°C for conditioning. The samples were thoroughly agitated for re-suspension of possibly settled solids and the appropriate volume of samples was poured into jar test beakers. Jar tests were set up at room temperature. Various amounts of coagulant were added into the beakers and the pH values were adjusted to the desired values by adding 0.1 N H_2SO_4 or 0.1 N NaOH. The experiment process consisted of 3 subsequent stages: the initial rapid mixing stage for 2 min at 80 rpm, followed by the slow mixing stage for 30 min at 30 rpm; and the final stage was settling for 3 hrs. Samples were then withdrawn for analytical measurements. The COD, colour, SS, zeta potential and particle size were determined.

Analysis of samples was made before and after each experiment. The removal efficiency was calculated as below

Removal (%) = $[(C_i - C_f/C_i) \times 100]$

where C_i and C_f are the initial and final concentrations in mg/L, respectively.

3. RESULTS AND DISCUSSION

3.1. Optimum concentration of PACl

Fig. 1 shows the removal efficiency of COD, SS and colour using various PACl concentrations. The optimum dosage of PACl was chosen at 6480 mg/L by considering the percentage removal of COD, SS and colour as shown in Fig. 1. The percentage of TSS removal was the highest at PACI concentration of 6480 mg/L which was nearly 98% but it decreased when the dosage was increased. At this optimum dosage of PACl, the concentration of SS decreased from 128 to 3 mg/L. The removal percentage of COD and colour was 66.3 and 82.9%, respectively at optimum PACl dosage. For PACl dosage higher than 6480 mg/L, the removal of both COD and colour was observed to be decreased (Fig. 1).

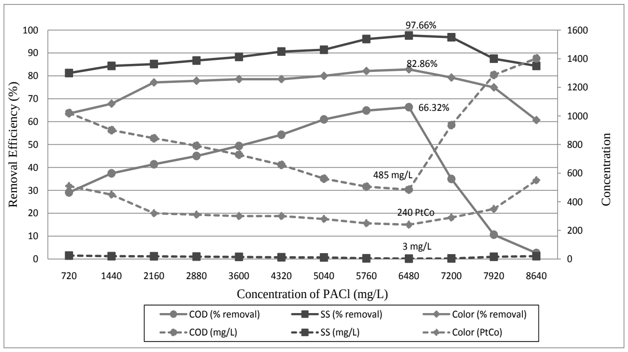

Figure 1. Removal efficiency of COD, SS and colour at various PACl dosages

The concentration of COD decreased to 485 mg/L from initial concentration of 1440 mg/L when optimum dosage of PACl was applied. However, a rapid increase in COD was observed when PACl dosage was increased beyond its optimum dosage and COD increased to 936 from 485 mg/L. According to Klimiuk et al. [24], the COD which could be removed from textile effluent using PACl ranged between 40-70%. An increase in COD removal at higher PACl dosage is primarily related to the production of bigger and more stable flocs, however, when the dosage keeps on increasing, the flocs become destabilized and smaller in size which ultimately results in decreased removal efficiency.

3.2. Optimum concentration of *Hibiscus rosa-sinensis*

Fig. 2 shows the removal efficiency of COD, SS and colour at various concentrations of *Hibiscus rosa-sinensis* leaf extract. The percentage removal of COD and colour was 10.9 and 17.2%, respectively. The concentration of COD decreased to 1283 mg/L from initial concentration of 1440 mg/L, whereas colour reduced from an initial concentration of 1400 to 1160 mg/L. Hence, *Hibiscus rosa-sinensis* was not effective in reducing the concentration of colour and COD from textile wastewater.

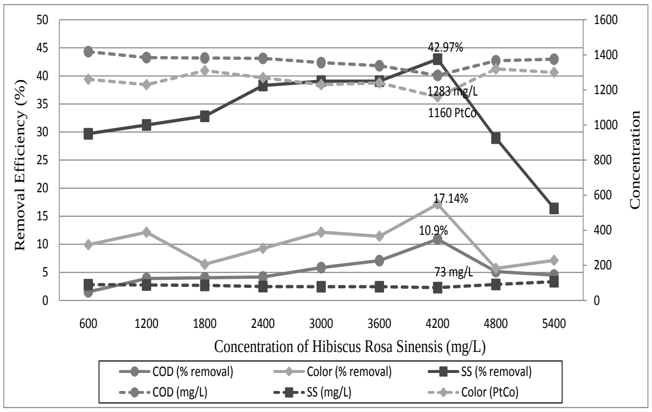

Figure 2. Removal efficiency of COD, SS and colour at various dosages of *Hibiscus rosa-sinensis* leaf extract

According to Gaceva et al. [25], there are more than 10,000 dyes incorporated in the Colour Index and available commercially, most of which were difficult to decolourize due to their complex aromatic molecular structure and synthetic origin. Therefore, mucilage of *Hibiscus rosa-sinensis* was insufficient to remove the colour from textile wastewater. As coagulant, *Hibiscus rosa-sinensis* showed better result in the removal of SS (42.7%). Hence, *Hibiscus rosa-sinensis* was relatively effective in SS removal as the removal efficiency was higher than 40%. Such a reasonable SS removal performance could have been due to the sticky nature of the polysaccharides present in *Hibiscus rosa-sinensis*, which resulted in the formation of bigger flocs. Because the bigger flocs settle relatively quickly, a reasonable decrease in the concentration of SS was observed.

3.3. *Hibiscus Rosa Sinensis* leaf extract as coagulant aid

Fig. 3 shows COD, SS and colour removal efficiency of *Hibiscus rosa-sinensis* leaf extract as coagulant aid. As the *Hibiscus rosa-sinensis* leaf extract was tested at optimum dosage of PACl, only a slight increase in the removal efficiency of these three parameters was recorded. By using *Hibiscus rosa-sinensis* leaf extract as coagulant aid, the removal rate of SS did not increase due to the effectiveness of PACl in removing SS. At optimum dosage, the removal efficiency of SS was 98.44% with final concentration maintained at 2 mg/L.

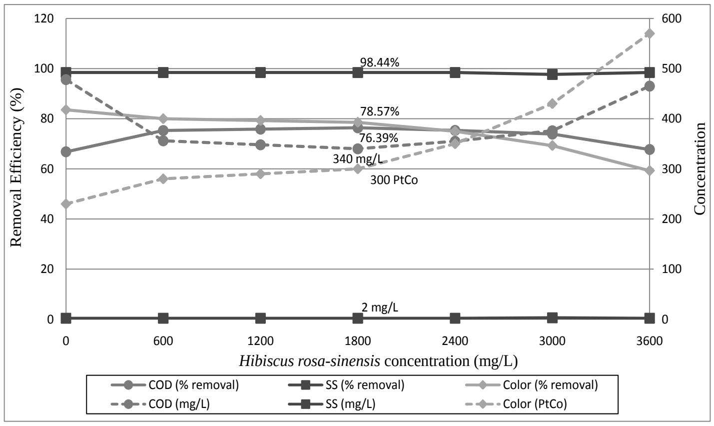

Figure 3. Removal efficiency of COD, SS and colour at optimum PACl dosage and various dosages of *Hibiscus rosa-sinensis* leaf extract as coagulant aid

Hibiscus rosa-sinensis leaf extract as coagulant aid increased the removal rate of COD (Fig. 3). At 1800 mg/L concentration of *Hibiscus rosa-sinensis* leaf extract, the removal rate was 76.4% which was 9.6% more than achieved at the optimum dosage of PACl. At the optimum dosage, the COD of textile wastewater reduced from 1440 mg/L to 340 mg/L. For colour removal, addition of *Hibiscus rosa-sinensis* leaf extract decreased the removal efficiency of PACl by 5%, hence, at concentration of 1800 mg/L *Hibiscus rosa-sinensis* leaf extract as coagulant aid, the removal efficiency of colour reduced to 78.6% from 83.6% when only PACl was used as coagulant. This might have been due to the carotene and chlorophyll content of *Hibiscus rosa-sinensis* which added greenish colour to the wastewater. The colour reduced to 300 PtCo from 1400 PtCo. As a result, optimum dosage of *Hibiscus rosa-sinensis* leaf extract was chosen at 1800 mg/L considering the removal of three parameters.

3.4. *Hibiscus Rosa-Sinensis* leaf extract as a coagulant aid in conjunction with low dosage of PACl

Fig. 4 shows the effect of *Hibiscus rosa-sinensis* leaf extract as coagulant aid (optimum dosage) on the removal of three parameters including COD, SS and colour at reduced PACl dosages. The removal of SS reached to 99.4% at a concentration of 3600 mg/L PACl. At this concentration, the SS reduced from 167 to 1 mg/L.

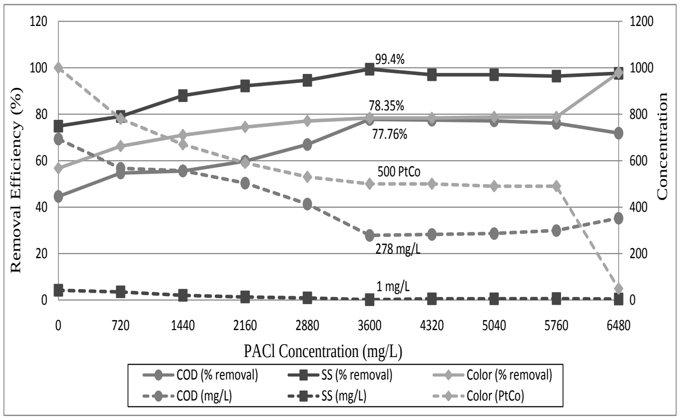

Figure 4. Removal efficiency of COD, SS and colour by using *Hibiscus rosa-sinensis* leaf extract (1800 mg/L) as coagulant aid at various PACl concentrations

On the other hand, the removal efficiency of COD increased to 77.8% at 3600 mg/L concentration of PACl in combination with *Hibiscus rosa-sinensis* leaf extract as coagulant aid which was 6% higher than when PACl was used as sole coagulant at relatively higher dosage of 6480 mg/L. As a result, the concentration of COD reduced from 1250 to 278 mg/L. Hence, *Hibiscus rosa-sinensis* leaf extract as coagulant aid rendered dual benefit in terms of reduced PACl dosage and improved COD removal efficiency. For colour, the removal efficiency slightly reduced as the PACl concentration was decreased. At concentration of 3600 mg/L, the removal efficiency was 78.4% which was only 0.4% less than 78.8% obtained at optimum dosage of 6480 mg/L PACl. Hence, the final value for colour was 500 PtCo compared to previous which was 2310 PtCo. However, as the concentration of PACl was reduced below 3600 mg/L, the removal efficiency was also reduced. As a result, the concentration of PACl could only be reduced from 6480 to 3600 mg/L. This implies that by adding *Hibiscus rosa-sinensis* leaf extract as natural coagulant aid at a concentration of 1800 mg/L, the concentration of PACl could be reduced up to 44%.

According to Sanghi et al. [26], Cassia seed gum proved an effective coagulant aid for direct and acid dyes because it could function as working substitute, partially or fully, for synthetic chemical coagulants such as PACl. This could, not only reduce the amount of toxic sludge formed after treatment which is difficult to handle and dispose, but can also make use of natural resources in a very constructive and efficient manner. In their [26] findings, colour removal enhancement with an added 1.5 mL dosage of Cassia seed gum was from 47 to 70% and 67 to 83% for ASR and DKG dyes, respectively. Coagulation with organic polymers followed by sedimentation could clean up industrial effluents when the flocs formed are dense enough.

3.5. Influence of pH

Fig. 5 shows the influence of pH on COD, colour and SS removals using the optimum dosage (6480 mg/L) of PACl. The pH of textile influent was adjusted to pH 2, 4, 6, 7, 8 and 10. The concentration of COD reduced from 1440 to 507 mg/L at optimum pH 7. For SS and colour, the concentrations reduced from 128 to 2 mg/L and from 1400 to 40 PtCo, respectively at pH 7. Results indicated that PACl worked better at neutral conditions. The removals of COD, SS and colour were 64.8, 98.4 and 83.4%, respectively. The removal rate deteriorated with increasing pH as shown in Fig. 5.

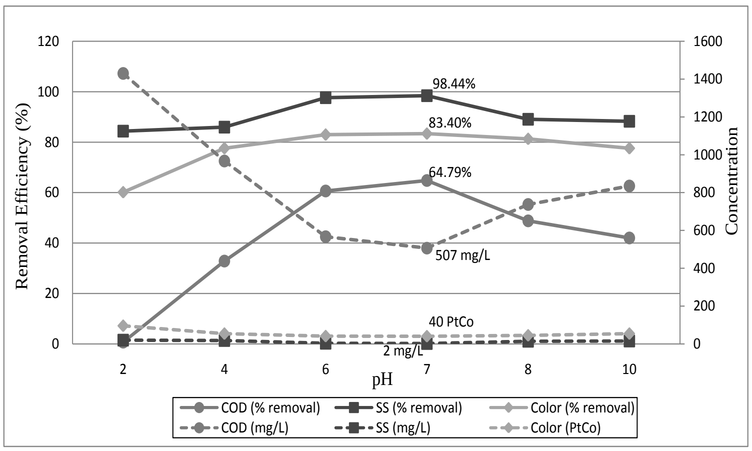

Figure 5. Removal efficiency of COD, SS and colour with varying pH at optimum PACl dosage

According to Gaceva et al. [25], PACl efficiency depends on pH. In their study, the best result using PACl to remove dye was at pH 7.1 where 76% colour was removed. Similar findings are reported by Lin and Peng [27] where the effect of pH on COD removal from textile wastewater appeared to be rather significant when PACl was used as coagulant at pH 7.

Fig. 6 shows the COD, SS and colour removal efficiency of *Hibiscus rosa-sinensis* leaf extract at various pH values. The pH of wastewater was adjusted to 2, 4, 6, 7 and 10. The optimum pH for *Hibiscus rosa-sinensis* leaf extract was 6. The results indicated that *Hibiscus rosa-sinensis* leaf extract worked better at slightly acidic conditions. The removal efficiency of SS at this pH was 42.2% whereby it reduced to 74 mg/L from initial concentration of 128 mg/L as shown in Fig. 6. COD reduced from 1440 to 1320 mg/L corresponding to a decrease of merely 8.3% (Fig. 6). On the other hand, colour reduced from 1400 to 1200 PtCo representing a reduction of 14.3% (Fig. 6).

However, the removal of all the three parameters deteriorated when pH was increased which implies that *Hibiscus rosa-sinensis* leaf extract was ineffective under alkaline conditions.

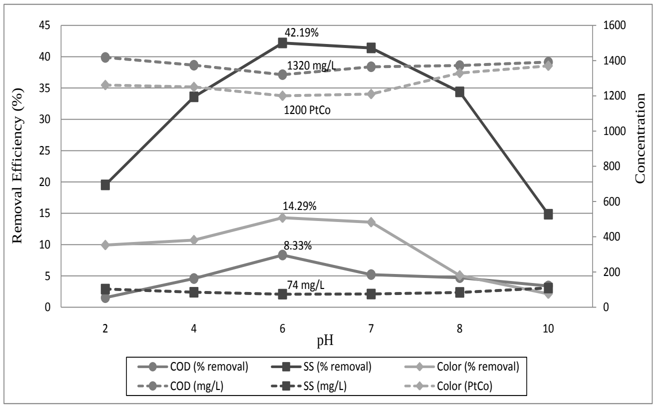

Figure 6. Removal efficiency of COD, SS and colour using *Hibiscus rosa-sinensis* leaf extract at various pH valu

Agarwal et al. [13] investigated the effects of pH on flocculation efficiency of okra gum in the treatment of sewage and reported 86% SS removal at maximum flocculation efficiency at pH 7. According to Yarahmadi et al. [28], the *moringa oleifera* seed extraction could remove 98.7% of the turbidity and the turbidity reduced to 6.2 NTU from its initial value of 500 NTU at an optimum dose of 10 mg/L and optimum pH 6.

Fig. 7 shows the removal efficiency of COD, SS and colour using optimum dosage of PACl and *Hibiscus rosa-sinensis* leaf extract as coagulant aid at various pH values. The results indicated that PACl as coagulant in combination with *Hibiscus rosa-sinensis* leaf extract as coagulant aid worked better at slightly alkaline condition (pH = 8). At pH 8, the removal efficiency of SS was 98.2% whereby the concentration of SS reduced from 167 to 3 mg/L. On the other hand, the second highest removal efficiency was recorded for colour which was 78.35% at pH 8. At pH 8, the colour reduced to 500 PtCo from its original value of 2310 PtCo. Lastly, COD reduced from 1250 to 307 mg/L which corresponded to a removal of 75.44%. In a nutshell, alkaline condition was more suitable for PACl to work with *Hibiscus rosa-sinensis* leaf extract as coagulant aid.

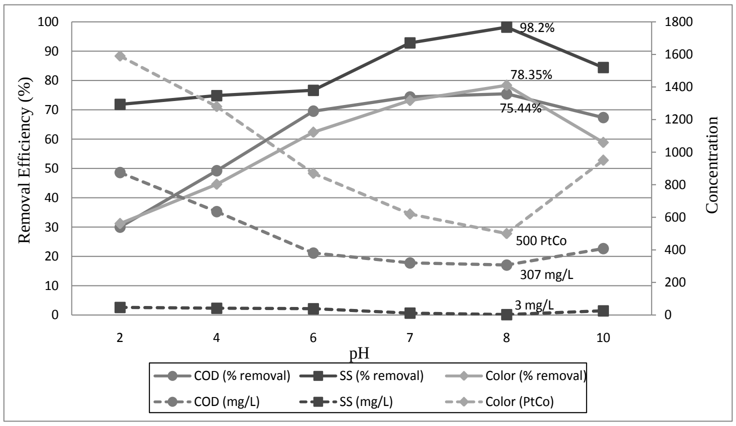

Figure 7. Removal efficiency of COD, SS and colour at optimum PACl and *Hibiscus rosa-sinensis* leaf extract as coagulant aid at various pH values

Sciban et al. [29] showed that increase in pH value had positive effect on coagulation activities of chestnut and acorn crude extracts especially at low investigated turbidity of water. According to Zonoozi et al. [30] bentonite acted best at pH 4 with PACl in removing acid red 398 dye from aqueous solution.

3.6. Influence on zeta potential and particle size

Figs. 8 and 9 show the effect on zeta potential and particle size when PACl and *Hibiscus rosa-sinensis* leaf extract were used as coagulants. As zeta potential and particle size has close relationship, the two parameters are discussed together. The labeled was the optimum pH of each coagulant where the removal of 3 parameters was at the peak. Firstly, when PACl was added as coagulant, the zeta potential decreased from -44.8 to -7.3mV at optimum dosage of 6480 mg/L.

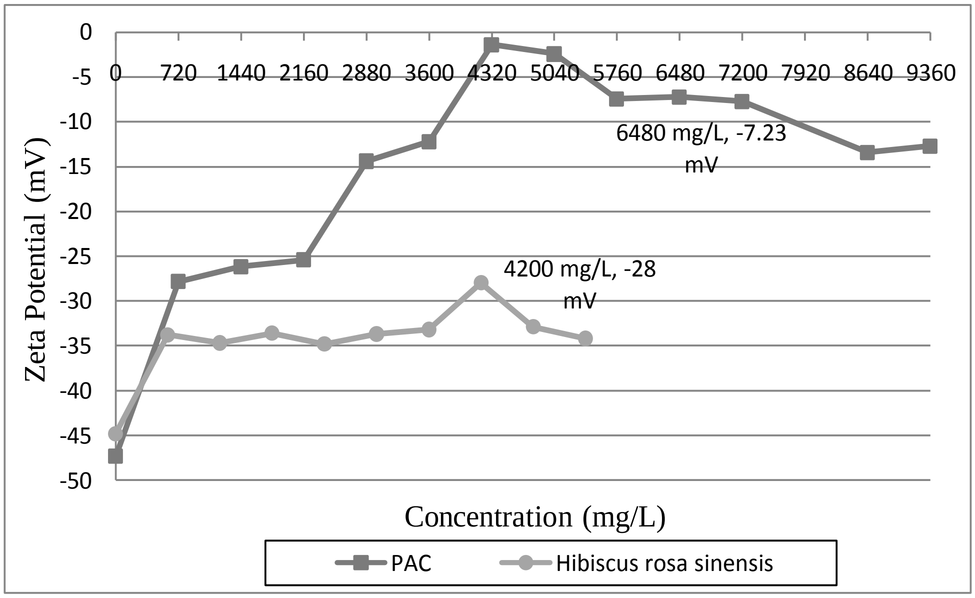

Figure 8 Comparative effect of PACl and *Hibiscus rosa-sinensis* leaf extract on zeta potential vs concentration

According to Gao et al. [31], an increase in polyamine dosage resulted in an increase of the zeta potential value. When the zeta potential reversal was observed, the maximum colour removal efficiency was observed. Generally, if charge neutralization is the only path for flocculation, the maximum removal efficiency was achieved when the zeta potential was close to zero.

The results indicated that the removal of dye was mainly due to charge neutralization. Although -7.34mV was not the lowest value for zeta potential, but according to Bratby [32] charge effect is not the predominant mechanism in many cases, although it might play a role during destabilization. Therefore, not only an adjustment to a given value of zeta potential (for example, zero) necessary lead to destabilization but destabilization might not be predicted by any particular value of zeta potential [32]. As a result, the particle size of flocs increased and reached to 60.54 µm at the optimum dosage of PACl (6480 mg/L). As zeta potential is a measurement of repulsive force and when the repulsive force is strong enough to keep particles apart, they remain in a state of dispersion. However, when the repulsive force is not strong, the particles would stick together in a permanent doublet leading the aggregates to settle. Theoretically, the best condition for particles to aggregate is at isoelectric point where it is absolute zero.

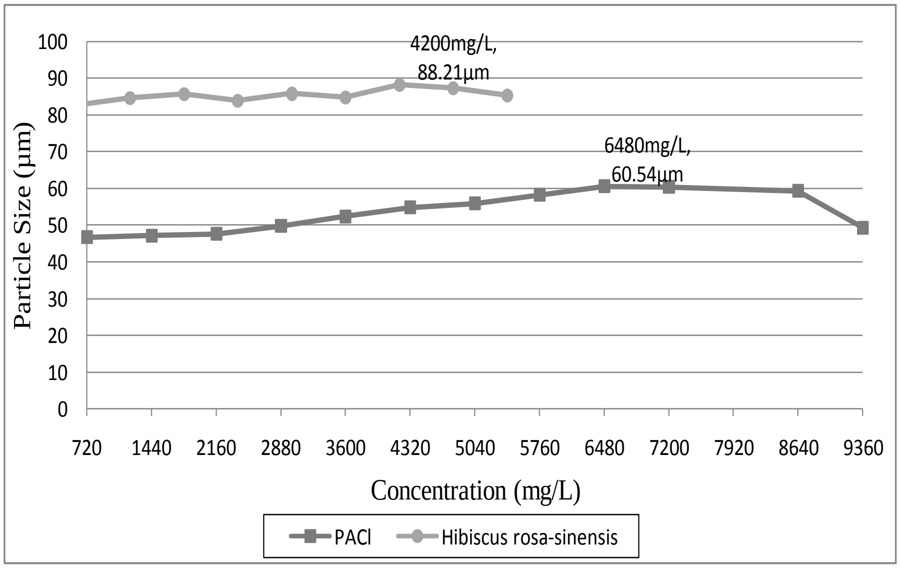

Figure 9. Comparative effect of PACl and *Hibiscus rosa-sinensis* leaf extract on particle size vs concentration

When *Hibiscus rosa-sinensisis* leaf extract was added as coagulant, the zeta potential reduced from -47.3 to -28 mV (Fig. 8) while the particle size increased from 20.34 to 88.2 µm (Fig. 9). Although the zeta potential was higher when *Hibiscus rosa-sinensisis* leaf extract was added, the particle size increased when compared to PACl. This was due to the sticky mucilage of *Hibiscus rosa-sinensis* leaf extract which aided the property of aggregation. However, the removal efficiency of *Hibiscus rosa-sinensis* leaf extract alone was relatively low compared to PACl. The zeta potential tended to become negative at optimum flocculation with an increase in molecular weight of the polyelectrolyte. This was mainly due to increasing molecular weight of flocculant by the addition of electrolyte or oppositely charged polyelectrolyte. In such cases, it is likely that some degree of charge neutralization occurs, the extent depending upon the system characteristics [33].

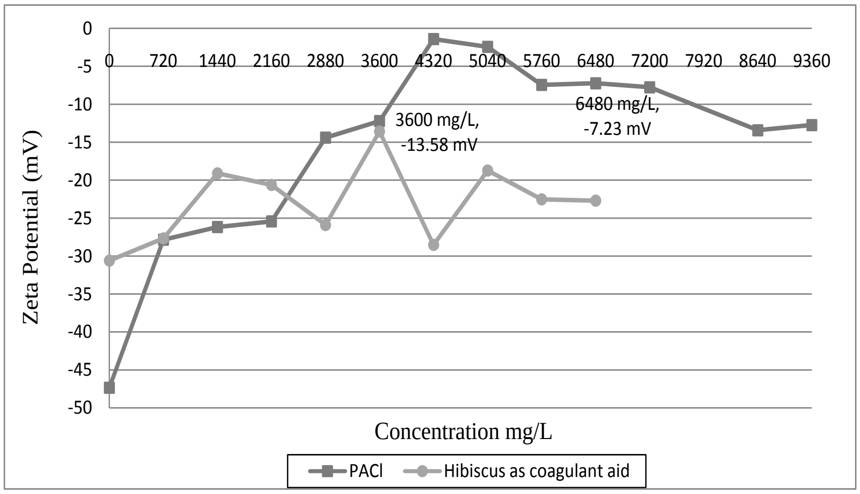

Figure 10 Comparative effect of PACl and *Hibiscus rosa-sinensis* leaf extract on zeta potential

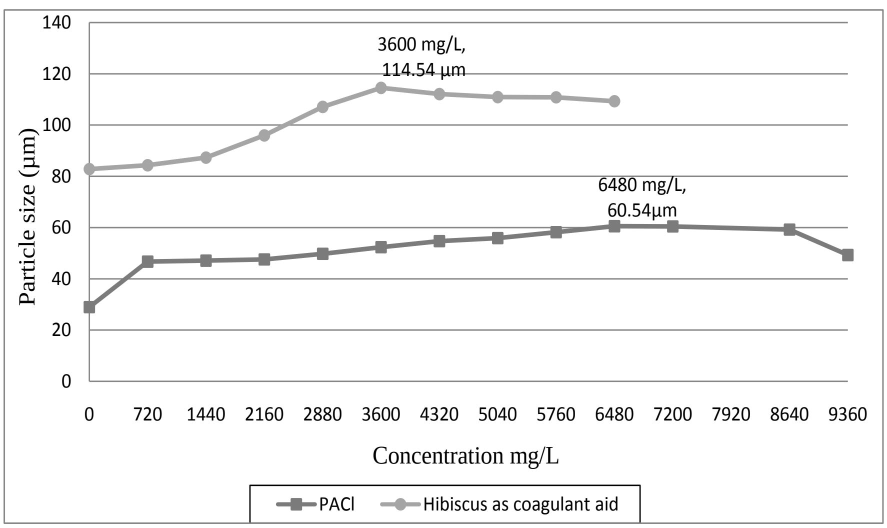

Figure 11. Comparative effect of PACl and *Hibiscus rosa-sinensis* leaf extract on particle size

Figs. 10 and 11 compares the effect of PACl as coagulant and *Hibiscus rosa-sinensis* leaf extract as coagulant aid on zeta potential and particle size. The value of zeta potential and particle size are labeled at the optimum dosage of both samples.
When PACl was added as coagulant, the zeta potential decreased from -44.8 to -7.23 mV at optimum dosage of 6480 mg/L.

Theoretically, zero zeta potential provides the best conditions for coagulation, however, when dealing with the heterogeneous suspensions found in water it seems there were many complicating factors and zeta potential measurements were not always of much value in operational circumstances [34]. The particle size reached the peak at 60.54 µm at the optimum dosage of PACl. However, when 1800 mg/L *Hibiscus rosa-sinensis* leaf extract was added as coagulant aid in combination with 3600 mg/L PACl, the zeta potential decreased from -30.6 to -13.6 mV at PACl concentration of 3600 mg/L (Fig. 10). At this concentration, the particle size increased from 82.9 to 114.5 µm (Fig. 11). An increase in particle's size results in the formation of bigger flocs which ultimately leads to enhanced settlement of particles and hence higher removal efficiency.

4. CONCLUDING REMARKS

The use of PACl as coagulant at optimum dosage of 6480 mg/L resulted in 66.3, 97.7 and 82.9% removal of COD, SS and colour, respectively. PACl worked better at pH 7 with removal efficiencies of 64.8, 98.4 and 83.4% for COD, SS and colour, respectively. *Hibiscus rosa-sinensis* leaf extract as coagulant proved ineffective with 10.9 and 17.14% removal for COD and colour, respectively. However, *Hibiscus rosa-sinensis* proved effective in removing SS with a removal efficiency of 43%. *Hibiscus rosa-sinensis* leaf extract worked better in slightly acidic conditions at pH 6. At optimum pH, the removal efficiency of COD, SS and colour using *Hibiscus rosa-sinensis* leaf extract was 8.33, 42.2 and 14.3%, respectively. The best fit of PACl and *Hibiscus rosa-sinensis* leaf extract was at concentrations 3600 mg/L for PACl and 1800 mg/L for *Hibiscus rosa-sinensis* leaf extract whereby the removal efficiencies were 77.8, 99.4 and 78.4% for COD, SS and colour, respectively. Compared with using PACl as the only coagulant, the removal efficiencies of COD and SS were enhanced except for colour when both coagulants were used. The removal efficiency of COD and SS was enhanced by 11.5 and 1.8%. The addition of *Hibiscus rosa-sinensis* leaf extract as coagulant aid decreased the removal efficiency of colour from 82.9 to 78.8%. In the case of zeta potential, when PACl was added as coagulant, the zeta potential of decreased from -44.8 to -7.3 mV at optimum concentration (6480 mg/L) while the particle size of flocs increased to 60.54 µm. When *Hibiscus rosa-sinensis* was added as coagulant, the zeta potential reduced from -47.3 to -28mV and the particle size increased from 20.34 to 88.2 µm. However, when *Hibiscus rosa-sinensis* leaf extract added as coagulant aid, the value of zeta potential decreased from -30.6 to -22.7 while the particle size increased from 60.59 to 114.54µm.

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