Australian Journal of Basic and Applied Sciences, 8(16) October 2014, Pages: 227-234

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Efficiency of Using Commercial and Natural Coagulants in Treating Car Wash Wastewater Treatment

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form
12 September 2014
Accepted 25 September 2014
Available online 2 November 2014

Keywords:
Car wash wastewater, Coagulation and Flocculation, Alum, Ferrous Sulphate, Moringa Oleifera, Strychnos Potatorum

ABSTRACT

The present study was performed to evaluate the efficiency of commercial and natural coagulants in treating car wash wastewater. The sampling campaigns on car wash wastewater samples were collected at Car Wash U Turn, Taman Universiti during the weekdays and the weekends' for 10 weeks. Two types of chemical coagulants; alum and ferrous sulphate ($FeSO_4$), and natural coagulants; *Moringa Oleifera* and *Strychnos Potatorum* were compared and were evaluated for different amount of dosages, ranging 30mg/L-200mg/L. These coagulants were used to treat car wash effluent and were evaluated for pH, chemical oxygen demand (COD), phosphorus, total suspended solid (TSS) and turbidity. The removal efficiency of both natural coagulants was more effective compared to low dosages chemical coagulants of 30-80mg/L. *Moringa Oleifera* showed 90% turbidity, 60% COD and75% phosphorus), whereas *Strychnos Potatorum* showed removal of 96% turbidity, 55% COD, 65% phosphorus. Data showed that the seed of *Moringa Oleifera* and *Strychnos Potatorum* contained coagulating substances capable of removing turbidity up to 99%. Meanwhile, for 150mg/L alum and $FeSO_4$, the results were 87% and 77% turbidity, 74% and 71%COD, and 81% and 65% phosphorus, respectively. Application of natural coagulant is recommended because it is eco-friendly and low cost as compared to chemical coagulants.

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To Cite This Article: Radin Maya Saphira Radin Mohamed, Nadira Mariam A. Ibrahim Kutty, Amir Hashim Mohd Kassim, Efficiency of Using Commercial and Natural Coagulants in Treating Car Wash Wastewater Treatment, ***Aust. J. Basic & Appl. Sci.,*** *8(16): 227-234, 2014.*

INTRODUCTION

The speedy growth of car wash service centre has seriously increased the contribution of pollution into bodies of water. In Malaysia, with total population of 28 million people, the vehicles sales report revealed that the total vehicle sales volume in the first half of 2012 (between January and June) was 301, 224 units and was forecasted to reach a new record of 615,000 units at the end of 2012 compared to 605,156 units and 600,123 units in 2010 and 2011, respectively (Malaysian Automotive Association, 2012). The increase in car volume on the road together with the already existing number of car definitely further boosts the car wash industry, leading to increased car wash services (Firdaus *et al.,* 2013). Based on the latest statistic, there are approximately 5.1 million vehicles registered in New South Wales (NSW) (Australian Bureau of Statistics, 2014). It is estimated that if each vehicle is washed using 40 litres of water (5 buckets) monthly, over 15 million litres of polluted water could enter the storm water system annually. This input stimulates the deterioration of natural water quality as many of the premises discharge their wastewater directly into main drain.

Wastewater from car washing centres contains a number of impurities such as sand and dust, free oil, grease, carbon, asphalt, salts, surfactants, and organic matter discharged directly into the municipal sewage treatment plant (Hamada and Miyazaki, 2004). The surface water contains more impurities in the form of suspended, dissolved and colloidal solids, bacteria, colouring and odour-inducing agents and organic matter. Fall *et al.* (2007) found through his study that the high concentrations of oil and grease, COD and TSS were 1100 mg/L, 4520 mg/L and 3561 mg/L, respectively derived from full service of the car wash sector such as wash lubricating shops in Mexico. Car wash wastewater mainly originates from traffic pollutants, car exploitation pollutants and car wash chemicals. Car washes produce an excessive amount of grits and sand and bring together oil and grease. Emulsified oils and suspended materials are the potential problem for the sewer system from the car wash wastewater.The suspended solid of colloidal ranges, and these fine turbidity particles

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often cause taste, odour and colour problems (Mazumder and Somnath, 2011).The untreated wastewater containing detergent can cause serious environmental problems because the detergent and its ingredients are relatively toxic to aquatic life (Hamada and Miyazaki, 2004; Mohamed *et al.,* 2013a; Mohamed *et al.,* 2013b; Chan *et al*., 2013; Chan *et al*., 2014). The detergents may also contain phosphates (Mohamed *et al*., 2014a), and elemental Na, Cl and Boron (Mohamed et al., 2014e) which can cause excess algae to grow in local waterways such as in the drains or others waterway (Mohamed *et al.,* 2014b, Mohamed *et al.,* 2014c). These impurities should be removed or reduced before being discharged into the sewer. These problems can be solved by providing an appropriate and affordable treatment system to achieve dual purpose; economical solution to car wash centres and reduces the percentage of water pollution.

With the increasing awareness of environmental issues, it is a must to have an on-site car wash wastewater treatment be installed prior to the point of discharge. It is reported that treatment methods such as coagulation, chemical oxidation, absorption and filtration, are studied to be employed in the car wash industry, but many of them is cost burden to the car wash business owner. Reclaimed water, otherwise known as reused or recycled water from car wash treatment is getting popularity to the fact that water saving will be benefit to both business premises and environment (Metcalf *et al.,* 2006). For instance, almost15% of Belgian carwash already reused 55% of the wastewater using different techniques (Boussu *et al.,* 2008). Among all techniques, coagulation and flocculation processes are considered as the most efficient and economical treatment. The treatment method is famous in reducing suspended solid and turbidity is the coagulation and flocculation processes (Mazumder *et al.,* 2011). Zulfiqar *et al.* (2010) had performed a lab experiment by using alum as coagulant in primary treatment and hydrogen peroxide in secondary treatment and was found the COD, turbidity and TDS were reduced up to 93%, 94% and 74%, respectively.

The use of coagulants alum [Al_2 $(SO_4)_3.14H_2O$] and ferrous sulphate ($FeSO_4$, $7H_2O$) were well known use in many wastewater treatment. The use of *Moringa Oleifera* was promising coagulant as several researchers have reported their efficiency in removing turbid water (Ndabigengesere *et al.,* 1995; Narasiah *et al.,* 2002; Eman *et al.,* 2009; Aygun and Yilmaz, 2010; Salam *et al.,* 2010; Rajendran *et al.,* 2013; Radin Mohamed *et al.,* 2014). *Moringa Oleifera* seeds contain a natural cationic protein (MOCP) that can be used as an anti-microbial flocculant for water clarification. The information regarding the ability of *Moringa Oleifera* seeds to purify water is not new; the seeds have been used for water treatment for generations in countries like India and Sudan. Recent research has identified proteins of sizes ranging from 3 to 60 kDa (kiloDalton) as possessing coagulating ability. The protein(s) act as a cationic polyelectrolyte that binds to soluble particles, leading to large flocs in water. Stirring and mixing accelerate the electrostatic flocculation, causing the flocs to condense the contaminants (Rajendran *et al.,* 2013).

The nuts of a species of *Strychnos Potatorum* are commonly used in some parts of India to clear muddy water. *Strychnos Potatorum* seed extracts are anionic polyelectrolytes that destabilize particles in water through inter particle bridging. The seed extracts also contain lipids, carbohydrates and alkaloids containing–COOH and free –OH surface groups, which enhance the extracts’ coagulation capability. A mixture of polysaccharide fraction extracted from *Strychnos Potatorum* seeds contains galactomannan and galactan capable of reducing up to 80% solution turbidity. In all cases, the galactomannans are made up of a main chain of 1,4-linked D-mannopyranosyl residues bearing terminal d-galactopyranosyl units linked at the 0–6 position of some mannose residues (Rajendran *et al.,* 2013). Natural coagulant, *Strychnos Potatorum* had achieved efficiencies of 96.3% and 99.3% for turbidity removal by adding 0.25-3.5mg/L for raw water turbidity around 125NTU (Deshmukh *et al.,* 2013).

Coagulation and flocculation processesare a physical-chemical method widely used to treat wastewater. Among currently employed chemical unit processes in wastewater treatment, coagulation and flocculation have received considerable attention for yielding high pollutant removal efficiency (Mazumder and Somnath, 2011) and removal of colour (Mohamed *et al*., 2014d). The objectives of this study were to characterize the types of car wash wastewater and to establish a low cost treatment system using coagulation and flocculation processes tested with commercial and natural coagulants and to evaluate post-treatment water efficiency among coagulants. Additionally, we hope to reduce the cost of obtaining fresh and clean water since it is expensive nowadays. This process can offer a simple and economically acceptable alternative of treatment for car wash wastewater as well as promote the environment benefit.

MATERIALS AND METHODS

Car Wash Wastewater Sampling:

The carwash wastewater was collected on weekdays and weekends at three different times, 11.00 am, 2.00 pm and 4.00 pm. Samples were collected twice a week on Tuesday, Thursday, Saturday and Sunday at Car Wash U Turn, Taman Universiti (1°50'57.5"N 103°04'42.5"E). Car wash wastewater samples were taken using the grab sampling as accordance to the Standard Method for Examination of Water and Wastewater (APHA, 2005). Figure 1 shows the drainage where the samples were collected. The car wash wastewater samples were stored in the HDPE bottles that had been washed with distilled water to ensure their cleanliness and avoid mixing the samples with other materials before they were taken to the laboratory for analysis.

Fig. 1: Sampling location of car wash wastewater that passes through the drain at the case study

Raw car wash wastewater was collected and analyzed for the following parameters: pH using pH meter, conductivity using pH meter (Eutech Model), total dissolve solid (TDS) using USEPA Gravimetric Method, filtering method, total suspended solid (TSS) using the gravimetric method, turbidity using Attenuated Radiation Method, chemical oxygen demand (COD) using COD reflux method, and oil and grease using the Envision Platform Controller SPE- DEX 4790 Automatic Solid Phase Extraction System., and phosphorus were analyzed by the acid persulfate digestion method.

Jar test:

Sytrochnos Potatorum seeds were purchased from an ayurvedic medical shop in Chennai, India. They were powdered and sieved through 150ìm sieve, and a 2% suspension was prepared with distilled water. Due to their hard structure, these seeds could not be powdered in a grinder. Therefore, they were immersed in 50 ml water containing 2ml concentrated HCl. After a week, they were oven-dried for 24 hours between103°C to 105°Cand then grounded into powder form. *Moringa Oleifera* was purchased from a local market and was dried under the sun because it has been experienced that the "level of *polyelectrolyte* present in the kernels is substantially less during the wet season". Therefore, it is recommended that the seeds are harvested during the dry season only (Nirmala and Jadhav, 2012). Then, the seeds were grounded into fine particles. An amount of 10g of the prepared powder was suspended in 1L of distilled water, and the suspension was stirred using magnetic stirrer for 10 min to extract the coagulation active components. Both suspensions were then filtered through a rugged filter paper. The filtered solutions were called extracts. While, for alum and $FeSO_4$, the coagulants were in analytical grade.

Coagulation-flocculation and precipitation studies were performed in a six-place conventional jar-test apparatus, equipped with 6 beakers of 1L volume using different coagulants of different dosages. Before the coagulation/flocculation process, the wastewater sample was thoroughly shaken to avoid any possibility of settled solids. The experimental process consisted of an initial rapid mixing stage that took place for 10 min at 120 rpm, followed by a slow mixing stage for 30 min at 60 rpm and a final settling step for 1 h. After 1 hour of settling period, samples were withdrawn from the supernatant for analyses of pH, turbidity, COD and phosphorus.

Data Analysis:

The data of raw car wash wastewater were tabulated, and the results of the concentrations were recorded in Microsoft Excel. The *Sigmaplot Software* 12.5 graphs were plotted. Analyses were done to characterize raw car wash wastewater (pH, total solid, total suspended solid, COD, oil and grease, and phosphorus) and to determine the efficiency of different coagulants consisting of chemical coagulants (Alum & $FeSO_4$) and natural coagulants (*Moringa Oleifera* & *Strychnos Potatorum*). The removal % efficiency of each coagulant before and after the coagulation process was calculated. The data show the performance of coagulation and flocculation of car wash wastewater samples on weekdays and weekends.

RESULTS AND DISCUSSION

Raw Car Wash Wastewater Quality:

The raw car wash wastewater characteristics for different samples are presented in Table 1. Data considered were those collected on the weekend and weekdays. When comparing all parameters between the weekdays and the weekends, samples collected on the weekends showed higher turbidity, pH, COD, TSSS and oil and grease. The difference in the parameters values could be due to the increasing number of vehicles, from 5 vehicles on the weekdays to 13 on the weekends.

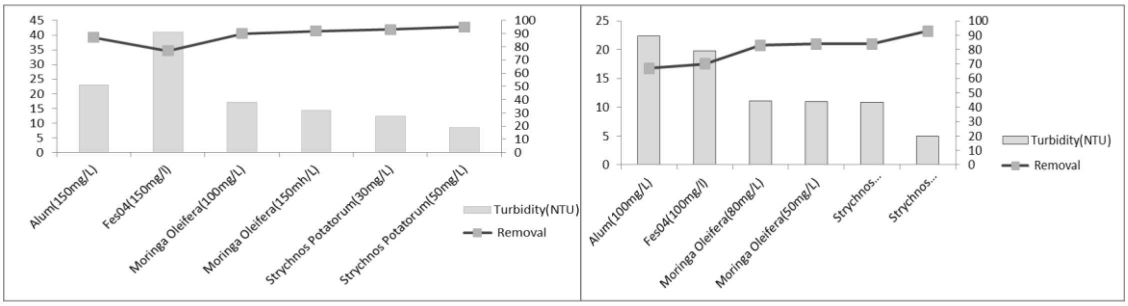
Table 1: Characterisation of raw car wash wastewater (mean value ± standard deviation) for weekdays and weekend for sampling regimes of 25th February, 26th February, 4th March and 11th March 2014.

Parameter	Weekdays		Weekends	
	Sample 1	Sample 2	Sample 1	Sample 2
pH	8.68 ± 1.621	7.85 ± 1.222	8.8 ± 0.507	8.27 ± 0.6558
Conductivity (µS)	137	125	189	235
TSS (mg/L)	147 ± 83.72	82 ± 25,238	202 ± 10	126 ± 75.147
Turbidity (NTU)	180.3 ± 51.926	68 ± 19.313	216.33 ± 21.548	173.67±58.76
COD (mg/L)	721.7 ± 105.458	681.3 ± 27.392	849.67 ± 233.140	893.33 ± 297.942
Oil and grease (mg/L)	1.78×10^{-3}	-	4.15×10^{-3}	2.08×10^{-3}
Phosphorus (mg/L)	6.36	2.79	8.63	7.3

Effect of Coagulants on Turbidity:

The wastewater generated from car wash contains detergents, shampoo and diesel, and materials that make it very turbid. Figure 2 shows different dosages showed different amount of turbidity reduction. The highest removal of turbidity was by samples containing *Strychnos Potatorum*, from an initial turbidity of 180.3 NTU to 12.4 NTU with a dosage of 30 mg/L. Increasing the dosage to 50 mg/L resulted in the highest number of reduction, down to 8.47 NTU. The turbidity percentage of car wash water that suitable to be reclaimed was close to 95% using the natural coagulant *Strychnos Potatorum*. It contains proteins, alkaloids, carbohydrates and lipids. The seeds of *Strychnos Potatorum* also contain strychnine, which is responsible for the coagulating properties (Nirmala and Jadhav, 2012).

The removal efficiencies for car wash wastewater samples on weekdays and weekends were 90 and 92%, which implies that *Moringa Oleifera* seed extract was satisfactory for high and low turbid water if it is properly applied. The variation in performance could be due to different protein contents in the seeds and their development in different geological locations (Narasiah *et al.*, 2002).



a)Weekdays b) Weekends

Fig. 2: The effect of different coagulant dosages on turbidity and removal % for different wastewater samples on (a) weekdays and (b) weekends

Effect of coagulants on COD:

The wastewater from car wash contains chemical substances from detergents, oil and grease, tyres and others. Thus, COD parameter needed to be analysed as it has to be reduced in order to reuse the car wash wastewater. In figure 3, an initial COD of raw wastewater samples were 721.7mg/L and 849.67mg/L for the weekends and the weekdays, respectively. The difference in COD could be due to the increasing number of vehicles, from 5 on the weekdays to 13 vehicles on the weekends. Alum had higher percentage of COD with 80%reduction compared to other coagulants. This was followed by $FeSO_4$, which was the second efficient coagulant in removing COD from car wash wastewater. The final results were in the range of 77%.The decrease in COD concentration had a direct relationship with the increasing dosage of coagulant. Alum was a very

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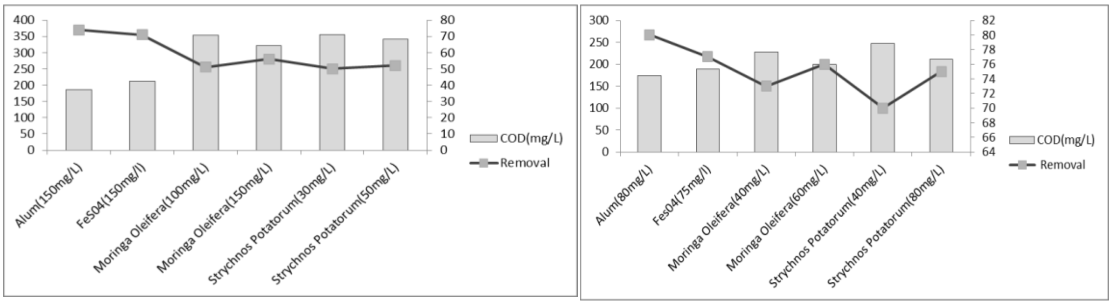
efficient coagulant for COD reduction. It was found to be an effective coagulant in reducing solids, organics and nutrients in industrial effluent for reuse in irrigation (Zulfiqar *et al.,* 2011). Zulfiqar *et al.* (2011) showed 93.35% percentage reduction using alum at 80 mg/L concentration. Alum doses above 80 mg/L may cause increased TDS and COD due to the release of excessive aluminum species into wastewater if the opposite charged particles are insufficient.

Moringa Oleifera showed a final COD reduction in the range of 320-360mg/L (50%). *Moringa Oleifera* seeds have also been found to have antibacterial activity, in which this coagulant can also be used to reduce COD. *Strychnos Potatorum* showed 60% COD removal. A study by Sonal (2012) showed COD was reduced from 100000 mg/L to 40 mg/L for turbid coloured water by using *Strychnos Potatorum*. The use of *Moringa Oleifera* gives COD reduction percentage of 60% at 60 mg/L of *Moringa Oleifera* in similar approach of car wash wastewater treatment in Parit Raja, Johor, Malaysia (Radin Mohamed *et al.*, 2014). In the form of powder derived from the crushed seeds of *Strychnos Potatorum* can act as a natural flocculent, which can eliminate a high amount of bacteria.

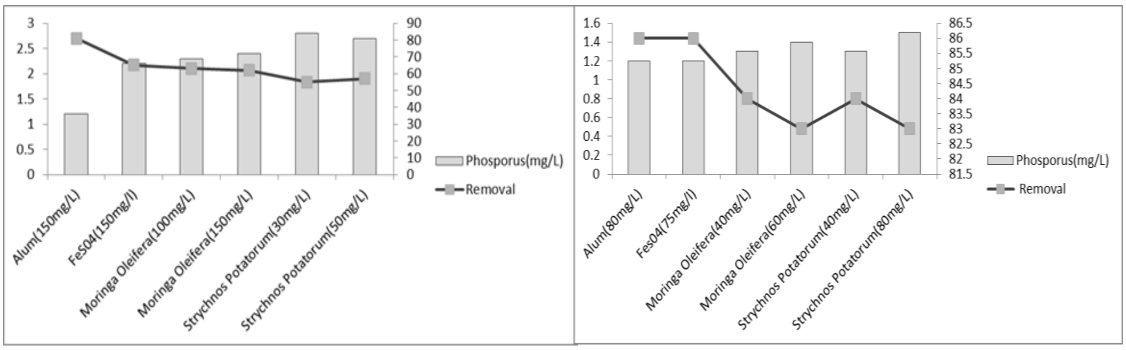


a) Weekdays b) Weekends

Fig. 3: The effect of different coagulant dosages on COD and removal % for different wastewater samples on (a) weekdays and (b) weekends

Effect of Coagulants on Phosphorus:

One of the major problems caused by discharging wastewater effluents into lakes and streams is water eutrophication. The removal of phosphorus from sewage effluents appears to be a practical way of limiting algal blooms in the receiving waters. Initial phosphorus concentration in raw car wash water for weekdays was 6.36mg/L. As shown in figure 4, phosphorus reduction using alum was highest at 1.2mg/L, while the lowest was using *Strychnos Potatorum* (80mg/L-1.5mg/L). Alum and $FeSO_4$ showed almost 80-85% phosphorus removal.



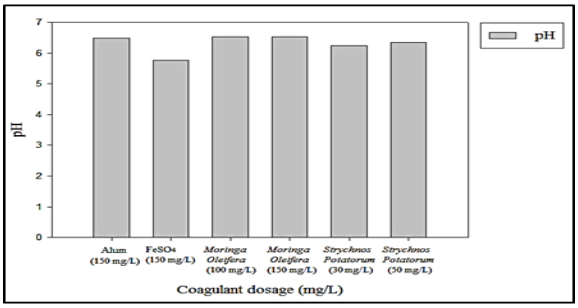
a)Weekdays b) Weekends

Fig. 4: The effect of different coagulant dosages on phosphorus and removal % for different wastewater samples on (a) weekdays and (b) weekends

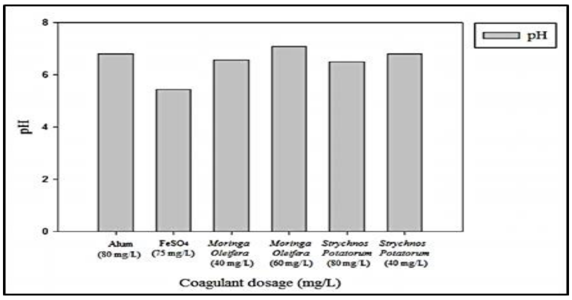
Effect of Coagulants on pH:

The results in figure 5 indicated that pH and conductivity of water samples were not significantly affected by *Moringa Oleifera* solution compared to alum. This offers a significant advantage for alum as coagulant because little or no further addition of chemical would be required to correct the finished water pH. Also, as light decrease in pH following the treatment with *Moringa Oleifera* seed solution could be due to hydrogen ions in *Moringa Oleifera* solution which balances the hydroxide ions in the raw water treatment.

The decrease in pH explained by the acidic character of Fe^{3+} or Al^{3+}. When reacting with OH^- ions, aluminum or iron will precipitate in the form of $Fe(OH)_3$ or $Al(OH)_3$ (O'melia, 2009). According to Stephenson and Duff (1996), the influence of pH on chemical coagulation/flocculation may be considered as a balance of two competitive forces: (1) between H^+ and metal hydrolysis products for interaction with organic ligands and (2) between hydroxide ions and organic anions for interaction with metal hydrolysis products.



a)Weekdays



b) Weekends

Fig. 5: The effect of different coagulant dosages on pH and removal % for different wastewater samples on (a) weekdays and (b) weekends

Conclusion:

This study has successfully revealed that seed extracts of *Moringa Oleifera* and *Strychnos Potatorum* are efficient in reclaiming wash water with 97% turbidity removal turbidity and pH from car wash wastewater by using coagulation and flocculation methods. Results obtained from the treatments with *Moringa Oleifera* and *Strychnos Potatorum* were encouraging, especially at optimum dosages (50-80 mg/L). Nevertheless, this study proves that using natural sources as coagulant led to higher percentage of removal from the wash water. The cost savings is obtained with the use of natural sources as coagulant, instead of buying chemical coagulant as tabulated in Table 2. Moreover, the chemical coagulants need to applied in high dosage for effective results. In contrast, natural coagulant only uses small dosage for greater removal.

Table 2: The efficiency and cost estimation of coagulants

Parameter	Coagulant	% Removal	Dosage (mg/L)	Cost
pH	*Moringa Oleifera*	Acidic/alkali to neutral state	Low dosage 60 mg/L	1kg *Moringa Oleifera* = RM 10.00
Turbidity NTU	*Strychnos Potatorum*	97% removal	Low dosage 50 mg/L	1 kg *Strychnos Potatorum* = RM 10.00
COD mg/L	Alum	80% removal	Low dosage 80mg/L	1 Bottle=RM122.00
Phosphorus mg/L	Alum and Ferrous Sulphate	80-85%	Low dosage of 60-70mg/L	1 Bottle of $FeSO_4$ =RM65.00

ACKNOWLEDGEMENT

The authors wish to thank the academic and technical staff especially at the Wastewater and Environmental Engineering laboratory and Analytical Laboratory of Faculty of Civil and Environmental Engineering for their analytical assistance and advice to cater our needs. The authors also thankful for the financial support from the Universiti Tun Hussein Onn Malaysia.

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