Moringa Oleifera and *Strychnos Potatorum* Seeds as Natural Coagulant Compared with Synthetic Common Coagulants in Treating Car Wash Wastewater: Case Study 1

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ABSTRACT— ***The present study is aimed to evaluate the efficiency of different types of coagulant; chemical (alum and ferrous sulphate) and natural coagulants Moringa Oleifera and Strychnos Potatorum for treating car wash wastewater. Car wash wastewater samples were collected at Radin Car Wash Parit Raja (geographical coordinates: 1° 52' 0" North, 103° 7' 0" East) during weekdays and weekends in 10 weeks sampling regimes. The coagulants were used to treat car wash effluent and were evaluated with respect to pH, chemical oxygen demand (COD), phosphorus, total suspended solids (TSS) and turbidity.The mixing started with rapid mixing of higher revolutions per minute (rpm) for 10 minutes and followed by the slow mixing at the lowest rpm for 30 minutes. The rotation speed was adjusted while carrying out the test to determine the optimum settling time. The coagulant was finally allowed to settle for 60 minutes. The experiments were started by obtaining the optimum fresh coagulants concentration and initial pH value of the car wash wastewater. The removal efficiency of both natural coagulants was more effective compared to chemical coagulants with low dosage, 40-80mg/L. Moringa Oleifera (94%-Turbidity, 60%-COD, 81%-Phosphorus) and Strychnos Potatorum (97%-Turbidity, 54%-COD, 82%-Phosphorus). Hence, the use of natural coagulants are apparently a better option as they provide better treatment and safe to environment, and the cost is cheaper to common coagulants in water treatment.***

Keywords— alum, car wash wastewater, ferrous sulphate, *Moringa Oleifera, Strychnos Potatorum*

1. INTRODUCTION

In recent years, wastewater is one of the major environmental problems arising in many densely populated and industrial areas of the world. Disposal of commercial and industry car wash wastewater can pose a significant threat to the health of our waterways, if allowed to enter the storm water system.In Korea, carwash wastewater is generated in various car washing sites at of approximately 0.5 – 1 m^3 car per day. Such effluents contain a lot of synthetic detergents, anti-freezing agent waste, waste oils and heavy metals and can cause a range of problems if they are not treated properly (Jiang *et al.,* 2005). In Korea, on-site community sewage treatment systems are designed to treat household wastewater. However, these systems do not provide adequate treatment for the types of contaminants found in commercial and industrial car wash wastewater. The mean removal efficiencies for different parameters oil and grease, chemical oxygen demand (COD) and total suspended solids (TSS) were as high as 80, 74 and 88 % respectively, but these values were not enough to comply with the requirements for discharge in the sewage system (Fall *et al.,* 2007). The car wash operational controls are essential to ensure that there is no on-site disposal of hazardous waste.

In Malaysia, water pollution is commonly contributed from residential wastewater (bath, laundry, sinks and kitchen) (Mohamed *et al.,* 2013a; Chan and Mohamed, 2013; Mohamed *et al.,* 2014a) and car wash wastewater where in most suburban areas were disconnected from the sewerage network. Increased water pollution increases the risks of respiratory, cardiovascular and neurological diseases, and affects people of all ages, from newborn children to the aged (Christine, 2010). Vehicle washing, in simple terms, involves cleaning the exterior and in some cases, the interior of motor vehicles. The use of detergents in many cleaning purposes may contain phosphates (Mohamed *et al.,* 2014a, Chan *et al*., 2014), which can cause eutrophication through excess nutrients in local waterways such as in the drains or others waterway (Mohamed *et al.,* 2013b, Mohamed *et al.,* 2014b, Mohamed *et al*., 2014c). Currently, most of the vehicles are washed unlawfully either at home or nearby rivers and streams. The contamination of water bodies by untreated car wash effluents is a prominent and serious environmental hazard. The car wash wastewater may include high levels of oil and grease, silt and unacceptable levels of acidity or alkalinity. The accumulated sediments or sludge may contain heavy metals such as chromium, lead, zinc and nickel (Sunday, 2014).Therefore, to avoid contamination of the receiving water bodies, there is an urgent need for the establishment of reliable treatment for commercial washing facilities across the country to protect the environment (Christine, 2010).

Previous studies performed by Debarata and Mukherjee, (2011) and Dahal (2012) revealed that the alum was efficient at low concentration of removing oil and grease (up to 300 mg/L). Chemical coagulation by alum and ferrous sulphate may be practiced for complete removal of oil and grease. Ferrous sulphate is an effective coagulant for the removal of oil and grease in the range of 300 – 600 mg/L, which is required in comparatively low amount. However, in such a case increasing the pH is essential to achieve alkaline condition. The use of natural coagulants of *Moringa Oleifera* and *Strychnos Potatorum* as natural coagulants was identified. Debarata and Mukherjee (2011) and Eman *et al.* (2009) carried out an experiment on coagulation and flocculation using *Moringa Oleifera* of industry wastewater. The process was improved by isolation of bioactive constituents from the seeds as coagulant/flocculant, which gave turbidity removal of 95.5%, 98.5% and 99.3% for the treatment of river water with low, medium and high turbidity respectively. The results has shown that the decreased dosage of coagulant to be added, which means decreasing the sludge volume being produced. *Moringa Oleifera* can be used as a natural coagulant/flocculant as an alternative to aluminium and other metallic salts in wastewater treatment. *Strychnos Potatorum* was found to be effective when used in low dosage, and itwas a good coagulant that gave higher turbidity of 1,000-3,000NTU in water treatment (APHA, 2005). The removal efficiency of *Strychnos Potatorum* solution was observed on the turbidity. The characteristics of commercial and natural coagulants are shown in Table 1.

Table 1: General information of the common and natural coagulants used in this study

Alum	Ferrous Sulphate	*Moringa Oleifera*	*Strychnos Potatorum*
$A1_2(SO_4)_3 + 3\ Ca(HCO_3)_2$ --> $2\ Al(OH)_3 + 3CaSO_4 + 6\ CO_2$ Aluminum + Calcium gives Aluminum + Calcium + Carbon Sulfate Bicarbonate Hydroxide Sulfate Dioxide (already in the water to treat)	$FeSO_4 + Ca(HCO_3)_2$ --> $Fe(OH)_2 + CaSO_4 + 2CO_2$ Ferrous + Calcium gives Ferrous + Calcium + Carbon Sulfate Bicarbonate Hydroxide Sulfate Dioxide (present in the water to treat)	-*Moringa* seeds possess antimicrobial properties reported that a recombinant protein in the seed is able to flocculate gram – positive and gram – negative bacterial cells.	-*Strychnos Potatorum* seed extract is an anionic poly – electrolyte which contains carboxyl (COO^-) and hydroxyl (OH^-) as main active groups. -It also contains proteins, alkaloids, carbohydrates and lipids. -The seeds of *Strychnos Potatorum* also contain strychnine which was supposed to be responsible for the coagulating properties

❖ Inorganic coagulants such as aluminum and iron salts are the most commonly used. When added to the water, they furnish highly charged ions to neutralize the suspended particles. The inorganic hydroxides formed produce short polymer chains which enhance microfloc formation. They produce large volumes of floc which can entrap bacteria as they settle.

The goal of car wash wastewater treatment is to remove as many parameters and biodegradable pollutants in wastewater as possible in order to minimise the risk towards public health and impact on the environment. It is imperative that the business must take proactive measures in both the quantity and quality of water as it relates to the professional car washing industry. It is important to the car care community that awareness is created not only on the amount of water used, but also on the content of the wastewater and solid waste collected from the business. Hence, the objectives of the study were to measure the characterization of raw car wash wastewater from selected case studies, to evaluate the efficiency of different types of coagulants, to assess the suitability of this method for wastewater treatment and the optimization of cost effective types of coagulant, as well as to investigate the effect of each parameter.

2. MATERIALS AND METHODS

Car wash wastewater samples were collected at Radin Car Wash Parit Raja (geographical coordinates: 1° 52' 0" North, 103° 7' 0" East). The samples were taken three times at 11.00 am, 2.00 p.m. and 4.00 p.m. to represent the average daily flow rate. The sampling processes were conducted on 23rd February 2014 and 2nd March 2014 for weekdays and 15th March 2014 and 21stMarch 2014 for weekends.This location was chosen because based on our observations; many customers preferred this car wash due to its strategic location, where the car wash is located in front of University residential. The containers that were used to collect the car wash wastewater samples were plastic containers (rinsed) as referring to the Standard Method of Examination of Water and Wastewater (APHA, 2005; Deshmukh *et al.*,2012).

Raw and treated car wash wastewater was collected and analysed for the following parameters: pH and conductivity using pH meter (Eutech Model); total dissolved solids(TDS) using USEPA gravimetric method; total suspended solids (TSS) using gravimetric method;turbidity usingattenuated radiation method; biochemical oxygen demand (BOD) using five–day test; chemical oxygen demand (COD) using COD reflux method; 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 followed by UV analysis.

The common coagulants, alum and $FeSO_4$ were purchased from the supplier (analytical grade). *Moringa Oleifera* with good quality dried drumstick was selected, and wings and coats from the seeds were removed. *Moringa Oleifera* seeds were then dried at approximately 24 hours and milled to fine powder using a domestic blender. Fine powder that passed through a 50-mesh sieve was then used as the coagulant (Suhartini *et al.*, 2013). *Strychnos Potatorum* was air-dried and crushed manually using mortar and passed through100 mm sieve. The soil was added to 5L of tap water, mixed thoroughly and allowed to swell in the water for about 24 hours. The suspension was blended in various high blending for 5 to 10 minutes. The blended portion was further diluted with water to obtain turbid suspension. This suspension was again allowed to settle overnight. The supernatant was decanted without disturbing the sediment and used as a stock turbidity suspension. The suspension of desired turbidity was then prepared by diluting the stock suspension by adding tap water.

The experimental works were carried out in a standard jar test for the coagulation and flocculation study. The jar test was equipped with six paddles that had adjustable rotating speed. For each batch of experiment, four different types of coagulants and dosages were used. The wastewater taken from the car wash in the amount of 6L was then divided into 1L per beaker. The wastewater in each beaker was mixed slowly before conducting any experiments. This was done to adjust the wastewater temperature to room temperature and suspend the solid, thus, preventing the solid from settling. These experiments also focused on the concentration of the treatment established. In order to distinguish samples, samples were identified as sample 1 and 2 for weekday and sample 1 and 2 for weekend. The coagulants used in water treatment to produce different types of coagulant. They were alum, ferrous sulphate, *Moringa Oleifera* and *Strychnos Potatorum*. Different dosages of coagulant are necessary to achieve good quality and effective percentage removal for each parameter.

The process started with rapid mixing of higher rpm for 10 minutes and followed by slow mixing of the lowest rpm for 30 minutes. The rotation speed was adjusted while carrying out the test to determine the optimum settling time. The coagulant was finally allowed to settle for 60 minutes. The experiments were started by obtaining the optimum fresh coagulants concentration and initial pH value of the car wash wastewater. Subsequently, alum and ferrous sulphate were used as the chemical coagulants and added with the natural coagulants of *Moringa Oleifera* and *Strychnos Potatorum* to increase the coagulation rate. The amount of the coagulant dosage was based on the efficiency of the coagulant from the previous studies. After 60 minutes, the supernatant was withdrawn after analyses.

The data analysis derived from this experiment provides characteristics of raw car wash wastewater and evaluation the efficiency of different types of coagulant. The experiments for raw car wash wastewater and jar test were conducted at the Environmental Engineering Laboratory. Illustrations of graphs were prepared using Microsoft Excel and Sigma Plot 12.5.

3. RESULT AND DISCUSSION

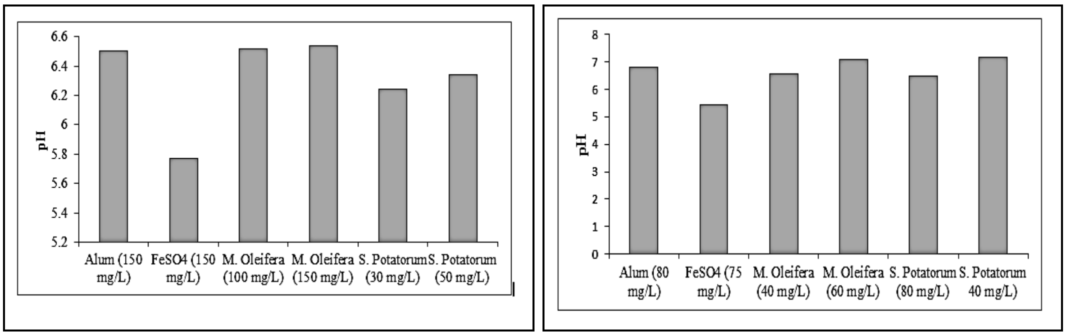
Changes in the quality parameters: Table 2 displays the characterization of raw car wash wastewater. The sampling process was done on the weekdays and the weekends of 23rd February 2014 until 21stMarch 2014. Based on the initial data, the average value of characterization parameter showed high load of pollutants, where the number of vehicles on weekdays increased from 6 to 15 vehicles compared to the weekends, where the number of vehicles was between 5and 10 vehicles. The analysis of effluent wastewater from a large number of automatic vehicle washing facilities in Goteborg, Sweden also exhibited a relatively high content of organic pollutants (Paxeus, 2011).

Table 2: The characterization of raw car wash wastewater (mean value ± ½ standard deviation) for the samples collected on the weekdays and the weekends of 23rd February 2014 until 21st March 2014

Parameter	Weekday February 2014		Weekend March 2014	
	Sample 1 23/2/2014	Sample 2 2/3/2014	Sample 1 15/3/2014	Sample 2 21/3/2014
pH	8.3 ± 0.374	9.61±0.07	8.0±0.66	9.07±0.59
Conductivity (µS)	224 ± 137	265 ± 125	235 ± 156	387 ± 189

TDS (mg/L)	556 ± 441	432 ± 385	445 ± 375	314 ± 431
TSS (mg/L)	186.3±56.6	93.33±44.88	14.33±2.08	22±3.61
Turbidity (NTU)	39.96±51.90	173.67±58.76	95.77±28.54	110.83±20.36
COD (mg/L)	741±315.53	337.33±101.55	572.67±84.91	312±164
BOD (mg/L)	355.33±65.68	269.67±143.73	460±53.51	297±70.76
Oil and grease (mg/L)	1.78±0.089	1.78±0.03	1.27±1.11	1.25±1.08
Phosphorus (mg/L)	5.51±0.31	2.79±1.50	7.3±7.72	10.34±5.94

Effect of coagulant on pH: Figure 1 shows that each coagulant gave different pH value effect. The pH value of raw car wash wastewater beforetreatment was in the range of 8.0 - 9.0. It was observed that after the treatment with alum, *Moringa Oleifera* and *Strychnos Potatorum*, the pH reduced to the range between 6.5 and 7.0.The optimum value of pH depends essentially on the properties of the water treated; type of coagulant used and its concentration (Abdul Aziz *et al*., 2007).The pH value for the coagulation study with ferrous sulphate was lower for every sample. In physical and chemical processes for car wash wastewater, both alum and ferrous sulphate acted on almost all characteristics. The effluent had a pH value of 5.7, which made it acidic. The pH of the treated wastewater decreased from 5.81 to 7.03 after the addition of different coagulants (Eman *et al.,* 2010). This means that all the desirable results of these reactions took place in a defined pH range depending on the nature of the water and is often found to be in the range of 5 to 7 (Kokila *et al.,* 2011).

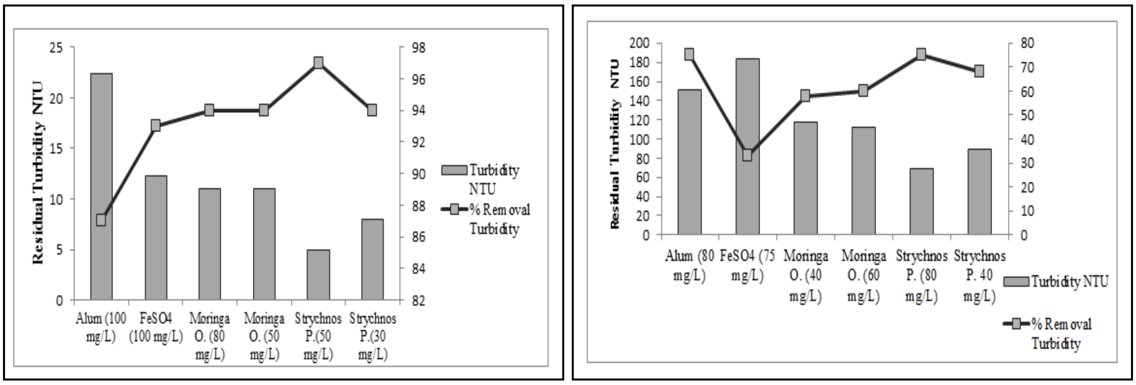


Sample 1 (weekdays) Sample 2 (weekend)

Figs. 1: Effect of different coagulant dosage on pH

Effect of coagulant on turbidity: According to Figure 2 shows the performance of alum, ferrous sulphate, *Moringa Oleifera* and *Strychnos Potatorum* in turbidity removal. The data collected on comparative performance of alum and ferrous sulphate as the common coagulants showed turbidity reduction from 99NTU to 8.47 NTU for weekdays and 174 NTU to 12.3 NTU for weekends. When the dosage for alum and ferrous sulphate of 100 mg/L and 150 mg/L were added, the residual turbidity was observed with 91% and 93% reduction. In terms of turbidity, the increment of turbidity removal can be observed with the increment of coagulant concentration, although the removal efficiency was almost steady due to alum and ferrous sulphate dosage increment in high coagulant concentration (Kokila *et al.,* 2011). The reduction of residual turbidity from 174 NTU to 5 NTU and 111 NTU to 35 NTU was achieved on the weekday and weekend samples with the optimum dosage of 50 mg/L and 80 mg/L of *Strychnos Potatorum* showed97% and 69% reduction respectively. The processed *Moringa Oleifera* performed well at low dosage to remove turbidity. From the results obtained, the initial turbidity of 278 NTU was reduced to 117 NTU and 112 NTU with 40 mg/L and 60 mg/L doses respectively.

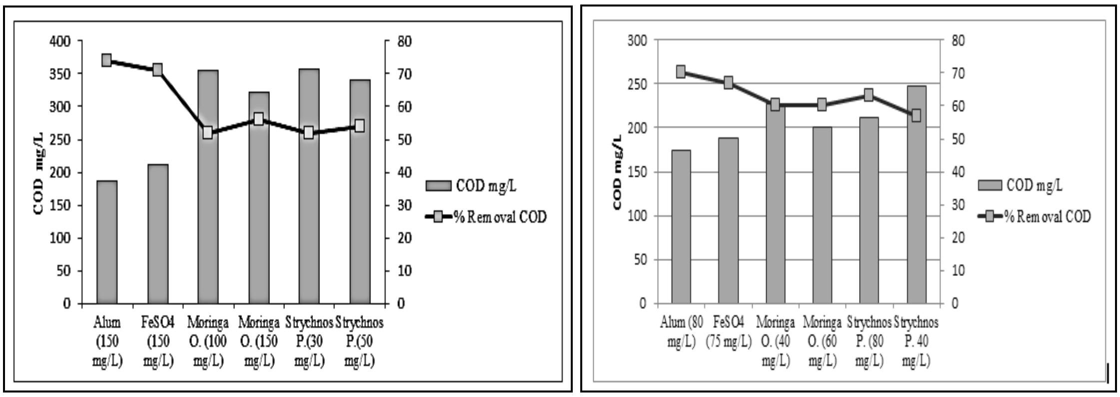
The natural coagulant *Strychnos Potatorum* shows effective removal of turbidity and has been used in the coagulation of wastewater treatment. Natural coagulants extracted from plants or animals can be workable alternatives to synthetic *Strychnos Potatorum* as they are biodegradables, safe for human health and have a wider effective dosage range for flocculation of various colloidal suspensions (Eman *et al.,* 2010). The study by Sanghi *et al.* (2006) on processed *Moringa Oleifera* showed turbidity removal of 95%, 98.5% and 99.3% for the treatment of wastewater using low dosage with low, medium and high turbidity respectively by using 0.05 mg/L, 0.15 mg/L and 0.30 mg/L doses. The experiment showed high coagulation activity for high turbidity and the performance of *Strychnos Potatorum* is useful for turbid water compared to performance of alum, ferrous sulphate and *Moringa Oliefera.*



Sample 1 (weekdays) Sample 2 (weekend)

Figs. 2: Effect of different coagulant dosage on turbidity and percentage removal

Effect of coagulant on COD: Chemical oxygen demand (COD) of car wash wastewater decreased after being treated with integrated treatment of coagulation and flocculation processes. Referring to the Figure 3, the decreased in COD concentration of weekday's samples had a direct relation with the increasing alum. The increase of alum concentration of 150 mg/L resulted in respective COD reduction from 741 mg/L to 187 mg/L. COD reduction percentage of 74% was observed. This showed that alum is a very efficient coagulant for COD reduction and is found to be effective in reducing solids, organics and nutrients in the industry effluent and reuse it in irrigation (Kokila *et al.*, 2011). The decreased in COD concentration had a direct relation with the decreasing concentration of *Moringa Oleifera*. With the decrease of *Moringa Oleifera* concentration to 40 mg/L and 60 mg/L, it caused respective COD reductions from 572 mg/L to 228 mg/L and 200 mg/L. The COD reduction percentage of 60% was observed at 60 mg/L of *Moringa Oleifera.* The study with ferrous sulphate showed that the optimum dose was 150 mg/L. The application of the coagulant showed high removal efficiencies and COD reduction. The increased of ferrous sulphate to 150 mg/L resulted in COD reduction from 741 mg/L to 212 mg/L. COD reduction percentage of 71% was observed. The study by Malhotra *et al.* (1964) showed that the COD reductions were 77.3%, 84.6% and 48.8% by ferrous sulphate in wastewater processing.

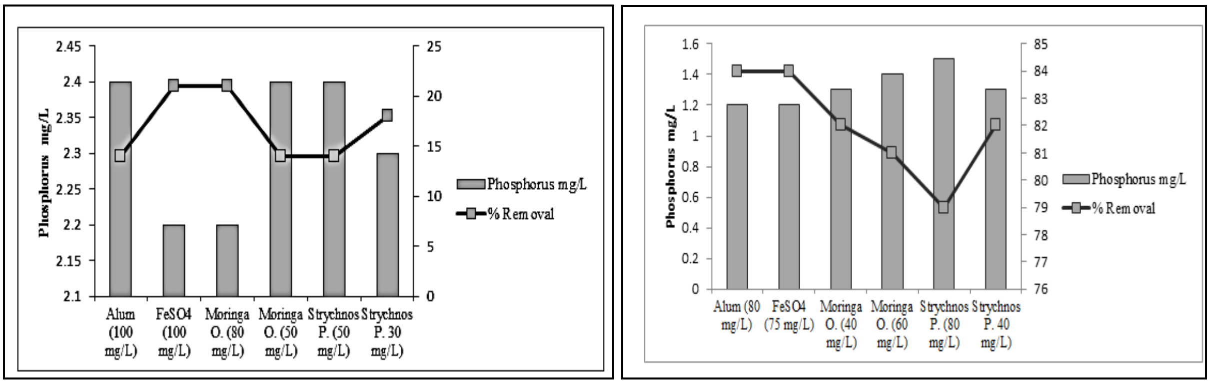


Sample 1 (weekdays) Sample 2 (weekend)

Figs. 3: Effect of different coagulant dosages on COD and percentage removal

Effects of coagulant on phosphorus: Chemical treatment for phosphorus removal involves the addition of metal salts to react with soluble phosphate and form solid precipitates which are then removed by solid separation processes including clarification and filtration. The most common metal salts used are in the form of alum (aluminium sulphate), sodium aluminate, ferric chloride, ferric sulphate, ferrous sulphate, and ferrous chloride. Overall, phosphate reduction was up from 78% to 87% at 150 mg/L and 60 mg/L of alum and ferrous sulphate dosages. It implied that the treatment with alum and ferrous sulphate was effective (Figure 4).

The results by Sanghi *et al.* (2006) showed that for runs 10 and 11 with pH adjusted to 6.0, an alum dosage of 250 mg/l removed 85% and 96% of the total phosphorus. This variability observed between runs can possibly be explained by the variation in the concentrations of one or more unknown components of the treated effluent. Part of the variation in these two runs is attributed to the different total phosphorus concentrations (Bhatti *et al.*, 2011). Ferrous sulphate is commonly used for municipal and industrial wastewater treatment. These salts are used as coagulants or flocculants, for odor control to minimize hydrogen sulphide release, for phosphorus removal, and as a sludge thickening, conditioning and dewatering agent. Ferrous sulphate controls hydrogen sulphide by binding one sulphide ion with each single ion of iron (Malhotra *et al.*, 1964).



Sample 1 (weekdays) Sample 2 (weekend)

Figs. 4: Effect of different coagulant dosages on phosphorus and percentage removal

The best effective coagulant from the experiment: The use of natural herbs purification purpose in countries is facing potable water supply problem due to inadequate financial resources. The cost of wastewater treatment is increasing, and the quality of wastewater is not stable due to suspended and colloidal particle load caused by land development and high storm runoff during the rainy season as experienced in Malaysia and others. Many coagulants have been widely used in conventional water treatment processes depending on their chemical characteristics. Many developing countries can hardly afford the high cost of imported chemicals for wastewater treatment (Mangale *et al.*, 2012). Due to many problems created by using synthetic coagulants such as aluminium sulphate (alum) and ferrous sulphate, there is a high demand to find an alternative coagulant which is preferable to be natural.

Naturally occurring coagulants are usually presumed safe for human health. Many researchers have reported on *Moringa Oleifera* and *Strychnos Potatorum* as ecofriendly and a cheaper method of water treatment. Chemtrade (2014) stated that *Moringa Oleifera* seeds do not give toxic effect and are of lower cost. *Moringa Oleifera* seeds can be used in the rural areas where no facility is available for wastewater treatment. In the study by Deshmukh *et al.,* (2013), *Strychnos Potatorum* was found to be an environmental friendly coagulant, which presented a viable alternative for the treatment of wastewater and turbid water. Table 3 shows the effectiveness of different types of coagulant based on estimation, removal and dosage.

Table 3: The effectiveness of different types of coagulant based on estimation, percentage removal and dosage (mg/L)

Parameter	Coagulant	% Removal	Dosage (mg/L)	Cost
pH	*Moringa Oleifera*	The effective changes of pH values from 7.0 – 8.0	Low dosage of 60 mg/L	1kg *Moringa* = RM5.00
Turbidity (NTU)	*Strychnos Potatorum*	97% removal	Low dosage of 50 mg/L	1 kg *Strychnos Potatorum* = RM10.00
COD (mg/L)	Alum	80% removal	Low dosage of 80mg/L	1 Bottle = RM122.00
Phosphorus (mg/L)	Alum and Ferrous Sulphate	80-85%	Low dosage of 60-70mg/L	1 Bottle = RM65.00

The uniqueness of the present study involves the usage of different types of coagulant. Table 2 shows the common coagulants and natural coagulant that effectively removed more than 90% of all parameters. The treatment of pH removal by using low dosage of *Moringa Oleifera* gave the respective value. Turbidity showed the highest removal of 97% when using *Strychnos Potatorum* at low dosage. The performance of chemical coagulant shows that it is very effective to remove COD and phosphorus.

4. CONCLUSIONS

This research produced the findings on natural coagulants *Moringa Oleifera* and *Strychnos Potatorum* of high efficiency and the parameter of pH removal values from 8.0 – 7.0 and 97% removal of turbidity using low dosages of50mg/L to 60mg/L. Common coagulants showed 70% COD reduction and removed 83% phosphorus with low dosage of 75mg/L to 80 mg/L. All four coagulants are very effective for removal of the parameters of car wash wastewater.

Based on this research, the natural coagulant is more cost effective compared to common coagulant, which is only RM10.00 per kilogram. The utilisation of natural coagulants provides an alternative way to lower the coagulants and flocculants cost and also to improve the water quality characteristics for safe utilization.

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