Influence of Type and Dose of Coagulants on Vehicle Wash Wastewater

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Abstract

The study was conducted to investigate the effect of the type and dosage of coagulant on changes in phosphate and fatty oil levels in liquid waste from motor vehicle wash. The independent variables in this study were the type of coagulant (Al2(SO4)3 and FeCl3) and the dosage of coagulant (0 ml, 3 ml, 5 ml, and 7 ml), while the dependent variables were the content of phosphate and fatty oil. The experiment was conducted in 3 stages; fast stirring, slow stirring, and precipitation. From the preliminary test, it was found that the phosphate content before processing was 12.9 mg/lt and the content of fatty oil was 1.9 mg/lt. The most significant decrease in phosphate content was found when 7 ml of FeCl3 was used as a coagulant; it dropped to 0.11 mg/lt (efficiency: 99.2%). Meanwhile, the most effective coagulant for fatty oil was 3 ml of Al2(SO4)3; the fatty oil content dropped to 1.4 mg/lt (efficiency: 30.7%). The addition of Al2(SO4)3 gave the opposite effect on phosphate and fatty oil, making the process ineffective. Meanwhile, the data showed that FeCl3 could be used as an effective coagulant for phosphate and fatty oil. To determine the significance of the differences between the results of the Randomized Complete Block Design analysis, the researcher used the Least Significant Design test. The results showed that the variation of the type of coagulant affected the decrease in phosphate and fatty oil levels, while the variation in dosage gave no significant difference.

***Keywords**: Phosphate, Fatty Oil, Coagulant, Motor Vehicle Wash*

1. Introduction

The increase in the number of motorized vehicles, along with the development of transportation, has indirectly given rise to washing services for vehicles, both motorbikes and cars. These vehicle washing service providers generally dispose of used washing water directly into the drain without any waste water treatment equipment. In fact, the waste water produced contains various pollutants; which, if not managed properly, will increase environmental damage and pollution, namely pollution of water bodies originating from liquid waste. Liquid waste from motor vehicle wash usually contains a lot of contaminants, including suspended solids, phosphates, fatty oils, motor oils, heavy metals, and other toxic substances such as phenol. The pollutants oils, for instance, may interfere with the entry of sunlight into the river, affecting the river ecosystem.

Phosphate plays an important role in detergents as a water softener. Phosphate can reduce water hardness by binding calcium and magnesium ions, boosting detergents' effectiveness and washing power. Phosphate comes from Sodium tripolyphosphate (STPP), which is the second most important element after surfactants due to its ability to deactivate water hardness minerals in water [1]. Although phosphate is not considered harmful to humans, the increase in its concentrations in aquatic ecosystems can promote the growth of microbes and algae, causing eutrophication [2]. Eutrophication of water bodies is a special phenomenon in ecosystems. This is caused by an increase in nutrients that stimulate the growth and reproduction of algae, resulting in a deterioration of the quality and condition of natural waters [3]. The problem of water eutrophication is often viewed only from the perspective of deteriorating water quality. However, it is also harmful to human health and contributes to the spread of gastrointestinal and skin diseases [4].

Oil in liquid waste from motor vehicle wash comes from lubricants sticking to engines washed away during washing [5]. Oil may interfere with the entry of sunlight and oxygen from the air into the water. It may also cause sedimentation, plugging drains and reduce the effectiveness of biological agents in the treatment of sewage. Liquid waste is typically dark yellow, cream-colored, very cloudy, has a pungent odor, and contains high amounts of sodium, nitrogen, phosphorus, and potassium [6]. Coagulation The flocculation process is an alternative treatment process commonly used to reduce phosphates and fatty oils in car wash fluid waste. [7]. The method is well known for its operation and its maintenance. The choice of coagulant agent is made based on its suitability, availability, and cost. Normally, the coagulants used are alum, polyelectrolyte and lime [8][9]. During coagulation, colloidal particles will pull each other and agglomerate to form flocs. Flocculation is a process after coagulation, the fusing of floc cores into flocs that may form sedimentations [10][11]. The purpose of flocculation/flocculation is to remove suspended colloid particles as the stabilized colloids help overcome their repulsive forces, resulting in particles agglomerating into flakes [12]. The coagulants commonly used are alum-based coagulants ($Al_2(SO4)_3$) and ferrum-based coagulants ($FeSO_4$, $Fe_2(SO4)_3$, and $FeCl_3$).

The flocculation/flocculation process typically consists of three separate processing stages. First, the appropriate chemicals are added to the wastewater stream and then agitated at high speed. The wastewater is then agitated at medium speed to form large flocs and promote settling. Third, the flakes formed during flocculation are allowed to settle and then separated from the wastewater stream [13][14].

Aluminum sulfate (alum) is one of the first known and most commonly used coagulants. Alum is available in liquid form with a concentration of 8.3% or in solid form (blocks, granules, or powder) with a concentration of 17%. Solid alum dissolves readily in water, but this solution corrodes aluminum, steel, and concrete, so a protective coating is required for storage. The chemical formula of alum is $Al_2(SO_4)_3.18H_2O$. However, commercially available alum probably only contains 14 H_2O [15].

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Ferric chloride is available in two forms; solid form (green-black powder, $FeCl_3$) and liquid form (dark brown liquid, $FeCl_3.6H_2O$). The solid form is hygroscopic, with the following characteristics: adsorption, coagulation, and precipitation [16]. The solution is very corrosive and difficult to dissolve and produces relatively high dissolved iron concentration in the effluent process [17].

2. Research Method

The research was carried out on a laboratory scale on liquid waste from motor vehicle wash. The materials used in this study were liquid waste from motor vehicle wash, and coagulants ($FeCl_3$ and $Al_2(SO_4)_3$). The materials used for phosphate analysis were H_2SO_4 95% Ammonium Ferrous Sulfate, Phenol Phatalin (PP), NaOH, Ammonium Molibat $SnCl_2$ and Aquadest [18]. The materials used in fatty oil analysis were Freon 1.1.2 trichloroethane or Freon 1,2,2 trifluoromethane [19]. The settling tank used is rectangular in shape with a pyramid-shaped base with a slope of 60 degrees. The stirrer used for the fast mixing process uses a venal disc-type turbine stirrer, while the slow stirrer, it uses a baffle system [20].

Initial analysis of the liquid waste showed a phosphate level of 12.8 mg/L and fatty oil of 1.9 mg/L, with a pH of 9. The liquid waste was then poured into the stirrer and mixed with 3 mL of $FeCl_3$ coagulant solution. The solution was stirred using a motorized mixer at 80 rpm for 2 minutes. After the fast stirring, the waste would undergo a flocculation process for about 4 minutes. After the stirring, the waste was inserted into a sedimentation tank, and the sedimentation took about 30 minutes. The liquid waste from the flocculation tank was an effluent that would be analyzed to find the phosphate and fatty oil levels. To obtain the average, the process was repeated three times [21]. After that, the same process was done with different dosages of $FeCl_3$: 5 mL and 7 mL, and with a different coagulant ($Al_2(SO_4)_3$) with the same dosage (3 mL, 5 mL, and 7 mL). As a control, an experiment was also done without using any coagulant (0 mL).

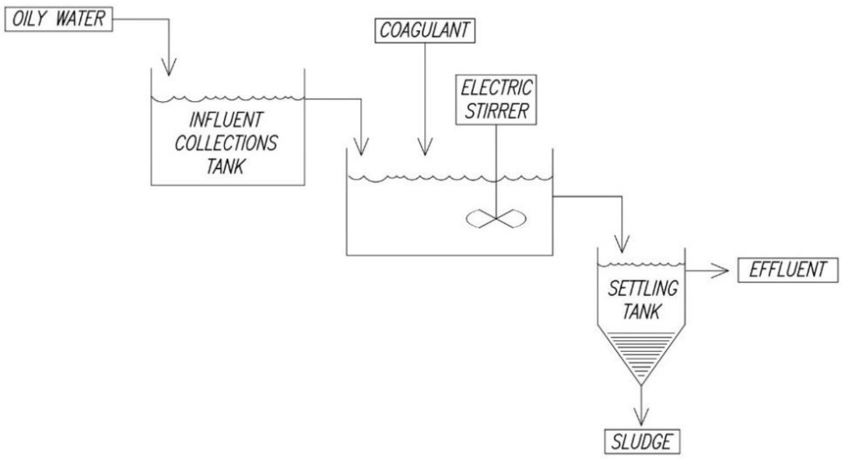

Figure 1. Set of Processing Tools

The formula for calculating the elimination percentage (%) of phosphate and fatty oil following the addition of coagulant was:

$$\% \text{ Rem} = \frac{(\text{C initial} - \text{C final})}{\text{C initial}} \times 100\% \quad (1)$$

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Note
% Rem : Removal percentage of phosphate and fatty oil after the addition of coagulant
$C_{initial}$: The level of phosphate and fatty oil before the addition of coagulant
C_{final} : The level of phosphate and fatty oil after the addition of coagulant

3. Findings

Based on the research that the results obtained after the experiments were :

Table 1. The average level of phosphate after treatment using various dosages of coagulants ($FeCl_3$ and $Al_2(SO4)_3$)

Coagulant	Dosage of coagulant (mL)			
	0	**3**	**5**	**7**
$FeCl_3$	7.4 mg/L	0.6 mg/L	0.2 mg/L	0.1 mg/L
$Al_2(SO4)_3$	7.3 mg/L	5.6 mg/L	2.3 mg/L	1.7 mg/L

Table 2. The results of pH analysis after treatment using $Al_2(SO_4)_3$ dan $FeCl_3$.

Coagulant	Dosage of coagulant (mL)			
	0	**3**	**5**	**7**
$FeCl_3$	9	7	6	5
$Al_2(SO4)_3$	9	7	7	6

Table 3. The average level of fatty oil after treatment using various dosages of coagulants ($FeCl_3$ and $Al_2(SO4)_3$)

Coagulant	Dosage of coagulant (mL)			
	0	**3**	**5**	**7**
$FeCl_3$	1.9 mg/L	1.8 mg/L	1.5 mg/L	1.3 mg/L
$Al_2(SO4)_3$	1.9 mg/L	1.4 mg/L	1.4 mg/L	1.4 mg/L

Table 4. The results of pH analysis after treatment using $Al_2(SO_4)_3$ dan $FeCl_3$.

Coagulant	Dosage of coagulant (mL)			
	0	**3**	**5**	**7**
$FeCl_3$	9	7	6	5
$Al_2(SO4)_3$	9	7	7	6

The data was analyzed using ANOVA with the Randomized Complete Block Design approach at a 5% level. Following that, a Least Significant Difference (LSD0.05) test was performed to examine the effect of dose changes on phosphate and fatty oil elimination.

4.1. Phosphate level

The most successful FeCl3 treatment was utilizing 7 mL of FeCl3, stirring for 2 minutes at 80 rpm, then flocculating for 4 minutes (effectiveness: 99.14%). Meanwhile, the most successful treatment employing Al2(SO4)3 was done with 7 mL of Al2(SO4)3, 2 minutes of stirring at 80 rpm, and 4 minutes of flocculation (effectiveness: 86.7%). This situation is consistent with recent study, which shows that orthophosphate removal efficiencies for alum and ferric chloride were 89 and 93%, respectively, at a dosage of 90 mg/L [22].

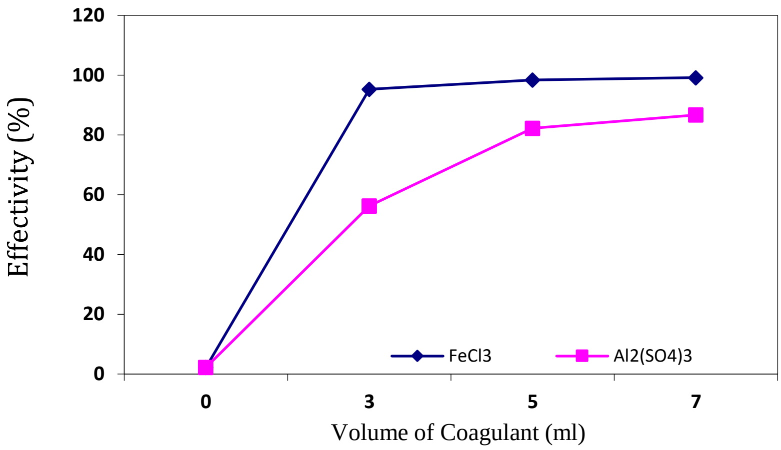

Figure 2. The Efficacy of Coagulant Therapy in Lowering the amount of Phosphate in the sample, based on the Volume Coagulant dose

$FeCl_3$ added to water will be hydrolyzed, forming $Fe(OH)_3$, which may bind with the particles of liquid waste such as PO_4^{3-}. $FeCl_3$ added to water will be hydrolyzed and produce Fe^{3+}, which function as cations that will bind with the anions of the dissolved particles in the liquid waste. The most effective phosphate removal occurred when 7mL of $FeCl_3$ was used, which reduced the pH of the liquid waste to 5 and formed $Fe(PO_4)_3$.

$Al_2(SO_4)_3$ added to water will be hydrolyzed, forming $Al(OH)_3$, which may bind with the particles of liquid waste such as PO_4^{3-}. $Al_2(SO_4)_3$ added to water will be hydrolyzed and produce Al^{3+}, which function as cations that will bind with the anions of the dissolved particles in the liquid waste. The most effective phosphate removal occurred when 7mL of $Al_2(SO_4)_3$ was used, which reduced the pH of the liquid waste to 6 and formed $Al_2(PO_4)_3$. The pH value decreases because the alkalinity of waste water is used to form metal hydroxide solids.

4.1.1. Analysis of Completely Randomized Design Data (Phosphate)

The significance of the changes in dosage of coagulant used on the level of phosphate was shown in **Table 5**.

Table 5. ANOVA of the Influence of the Dosage of Coagulant Used on the Level of Phosphate

	Sum of Squares	df	Mean Square	F_{count}	F_{tab} (α 0.05)
Between Groups	9.5647	3	3.1882	1.4108	9.28
Within Groups	52.4731	1	52.4731	23.22	10.13
Error	6.7796	3	2.2598		
Total	68.8174	3			

The calculation showed that the F_{count} of a source of variation between treatments (doses of coagulant) < F_{table} at a significance level of 0.05, showing that the variation of coagulant dosage had no significant effect on the removal of phosphate from liquid waste from motor vehicle wash. However, the F_{count} of source of variation between blocks (types of coagulants) > F_{table} at significance level of 0.05, meaning that variations in the type of coagulant used had significant effect on the removal of phosphate.

4.2 Fatty oil levels

The most effective treatment to remove fatty oil using $FeCl_3$ was done when 7 mL of $FeCl_3$ was used, with stirring time of 2 minutes at 80 rpm, and 4 minutes of flocculation process (effectiveness: 36.30 %). Meanwhile, the most effective treatment using $Al_2(SO_4)_3$ was done when 7 mL of $Al_2(SO_4)_3$ was used, with stirring time of 2 minutes at 80 rpm, and 4 minutes of flocculation process (effectiveness: 26.30 %). Other studies also showed that Aluminum sulfate (at a dosage of 2 g/L) was found to be an effective coagulant. The treated wastewater had an average removal efficiency of 89.6% for total solids, a pH of 4.15, and an optical density of 0.194 µm. A 20-liter fully automated prototype was then built for the treatment of grease filter wash water. Three distinct layers were visible: fat on top, liquid in the center, and sludge at the bottom. The technology effectively retrieved 80% recyclable water at a quality comparable to drinking water [23]. The most prominent comes about for COD (natural matter expulsion), turbidity expulsion, and oil and oil evacuation from wastewater were 96%, 92%, and 99%, individually. These values were gotten by including 700 mg/L FeCl3.6H2O to the emanating [24]. Other research also shows that result suggested that $FeCl_3$ has more advantages in phosphorous removal than $Al_2(SO_4)_3$ [25].

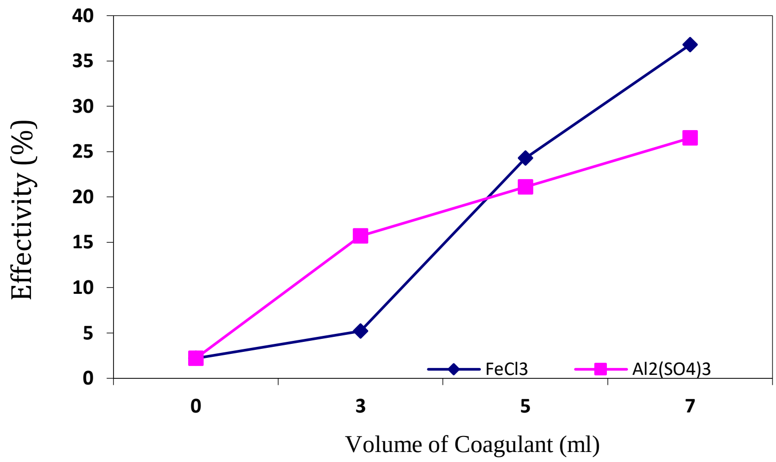

Figure 3. The Viability of Coagulant Treatment in Diminishing the Level of Greasy oil within the Test, based on the Measurement of Coagulant

The coagulation using $Al_2(SO4)_3$ caused a drop in pH from 9 to 7, 7 and 6. Meanwhile, the addition of $FeCl_3$ led to the drop in pH to 9, 7, 6 and 5, with the addition of 3 mL, 5 mL and 7 mL of coagulant. The higher the level of turbidity, alkalinity and organic matter, the higher the dose of coagulant required to form flocs. On the other hand, pH has a negative relationship with the dosage of coagulant. In other words, the addition of excessive coagulant in water causes the water to become acidic [26].

4.2.1 Analysis of Completely Randomized Design Data (Fatty Oil)

Table 6. ANOVA of the Influence of the Amount of Coagulant Used on the Level of Fatty Oil

	Sum of Squares	df	Mean Square	Fcount	Ftab (α 0.05)
Between Groups	0.0647	3	0.0216	0.8816	9.28
Within Groups	0.3721	1	0.3721	15.200	10.13
Error	0.0736	3	0.0245		
Total	0.5104	7			

The calculation showed that the F_{count} of source of variation between treatments (doses of coagulant) < F_{table} at a significance level of 0.05, showing that the variation of coagulant dosage had no significant effect on the removal of fatty oil from liquid waste from motor vehicle wash. However, the F_{count} of source of variation between blocks (types of coagulants) < F_{table} at significance level of 0.05, meaning that varieties within the sort of coagulant utilized had no noteworthy impact on the evacuation of greasy oil from fluid squander from engine vehicle wash.

4. Conclusion

The coagulation process occurs destabilization of colloids and particles in water as a result of the addition of coagulant accompanied by rapid stirring. Stable colloids and particles turn unstable because they break down into positively and negatively charged particles due to rapid stirring. Results of the study showed, increasing the dose of $Al_2(SO_4)_3$ will have the opposite effect on reducing phosphate and fatty oil. At high doses, phosphate can drop below the quality standard but makes the fatty oil content even greater and the processing process becomes ineffective. The addition of FeCl3 will make the processing process better but the pH of the waste water will become acidic. The most effective treatment was done when 7 mL of $FeCl_3$ was used (effectiveness: 99.14%) and the pH dropped to 5. Meanwhile, the most effective treatment to remove fatty oil was done when 7 mL of $FeCl_3$ was used (effectiveness: 36.30 %). The more coagulant added, the more effective the treatment will be; however, the water will become more acidic. In general, $FeCl_3$ is the more effective coagulant than $Al_2(SO_4)_3$. In further research to look for variations in coagulant dose, pH, speed gradient and residence time so that maximum processing results are obtained. The coagulation-flocculation process is influenced by pH and temperature, therefore further research is needed to find the right pH and temperature.

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