The Effectiveness of Activated Carbon and PAC in Reducing Phosphate Levels in Laundry Liquid Waste

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Keywords: laundry liquid waste, phosphates, activated carbon, PAC.

Abstract: The presence of excessive phosphates in water bodies causes a phenomenon of eutrophication that significantly enables algae and aquatic plants to multiply rapidly. The result of the laboratory test showed the average initial phosphate content of laundry liquid waste before the study was 18.4 mg/l. This research aimed at comparing the efficacy of activated carbon and Poly Aluminum Chloride (PAC) in minimizing the phosphate levels in liquid waste laundry X. The method used was a quasi-experiment research type with pre-test and post-test design. The population was all laundry X's liquid waste as much as 18 liters from the process of washing clothes collected by purposive sampling technique. The result of the research indicated that there was a decrease in the average level of phosphates after the addition of activated carbon of 1 gr, 3 gr, 6 gr by 8.16 mg/l while PAC of 1 gr, 3 gr, 6 gr by 4.66 mg/l. Thus, there is different effectiveness of activated carbon and PAC in reducing phosphate levels. The addition of PAC with a dose of 6 grams is more effective in reducing phosphate levels in laundry liquid waste.

1 INTRODUCTION

The increasing number of populations is directly proportional to the growing needs for goods and services. One of the fastest-growing industries nowadays is the laundry service (Wasserbaur et al., 2020). However, it could have both positive and negative impacts. The positive implications for service users are the affordable costs, time and energy saving, and less burden of household activities. By contrast, its negative impact is the occurrence of pollution and environmental damage due to the direct discharge of laundry liquid waste to water bodies (Gordon et al., 2009). Laundry liquid waste contains chemicals with high concentrations, one of which is phosphate (Ahmad and EL-Dessouky, 2008).

Phosphate is one of the nutrients which aquatic plants need to grow and develop their lives (Xiong et al., 2017). The presence of excessive phosphate in water bodies causes a eutrophication phenomenon (Miyazato et al., 2020). Therefore, in the laundry industry, liquid waste that has been produced must not be discharged directly to the environment. It must be treated in advance so that it has a quality that is in accordance with the established regulations (Khosravanipour et al., 2019). For this reason, there are several conventional techniques for treating industrial laundry liquid waste, one of which is chemical treatment using activated carbon and Poly Aluminum Chloride (PAC) (Manouchehri and Kargari, 2017).

A study showed that administering a dose of activated carbon of 1 g L^{-1} can reduce the maximum phosphate content of 102 mg g^{-1} (Mojoudi et al., 2019). Likewise, the administration of an activated carbon dose of 3 grams can reduce the highest levels of phosphate, which is around 1.89 mg/l (Majid et al., 2017). On the other hand, a study portrayed that after being treated with the addition of PAC with each dose of 0.3 gr; 0.4 gr; 0.5 gr; 0.6 gr; and 0.7 gr, the phosphate levels decreased by 1.83 mg/l (43.69%), 1.48 mg/l (54.46%), 1.43 mg/l (56%), 1.34 mg/l (58.77%) and 1.08 mg/l (66.77%). The results of these studies indicate that the administration of PAC has been effective in reducing phosphate levels to reach the quality standards of the Central Java regional regulation that is equal to 2 mg/l (Andriani, Darundiati and Dangiran, 2017). Also, the study by Chhetri et al.

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(2017) showed that giving a dose of PAC 7.5 mg Al/L can reduce phosphate levels up to 28%. In accordance with that, PAC also can reduce phosphate levels up to 72% (Chu et al., 2018).

The research methods used in the previous researches were descriptive research utilizing laboratory experiments starting from the preparation stage, such as the preparation of activated carbon solutions, namely making ready-to-use solutions for the examination of phosphate parameters by repeating the treatment two times (Majid et al., 2017). On the other hand, research conducted by Andriani, Darundiati and Dangiran (2017) used a true experimental research method with the posttest control group design. This study used only one treatment medium and did not make any comparisons.

This study conducted a quasi-experimental method with pre-test and post-test design. The reduplication of the treatment was three times, which was more than the study of Majid et al. (2017). Thus, the result was far more accurate than the two times repetition of the treatment. Even, a research conducted by Andriani, Darundiati and Dangiran (2017) only used activated carbon alone. We can infer that the more treatment comparison media used, the better it will be to know which one is far more effective. Based on the above context, research using activated carbon and PAC is required to highlight the comparison of the efficacy of the adsorbent and coagulant ingredients in reducing phosphate levels in laundry liquid waste.

2 METHOD

The location of the study was at the Laboratory of the Center for Environmental Health Technology and Disease Control Class I Medan. The population in the study was laundry X's liquid waste from clothes washing activities. In this study, the total number of samples required was 18 liters. Each treatment required one liter with three repetitions. The samples in the study were collected by purposive sampling technique based on the considerations made by the researchers themselves. The inclusion criteria were the laundry liquid waste should be from the first washing process that comes out of the disposal outlet and has not yet been treated.

The materials used were laundry liquid waste, activated carbon, PAC, and aquades. The instrument used to measure phosphate levels at the pre and posttest was spectrophotometry. There were several stages, namely: the preparation stage where the laundry liquid waste samples were carried out using dilution because it was too concentrated; Then, prepare the entire test sample, then pipette 2.5 ml into an Erlenmeyer, then add aquades then cover it and after make it homogeneous. For the pretest sample, the stages were: a sample that had been diluted before was pipetted as much as 10 mL, added ten drops of $PO4^{-1}$ reagent into a test tube, made in the vortex until being homogeneous, added $PO4^{-2}$ reagent of 2 micro spoons (vertically done when adding reagents), made in the vortex until being homogeneous and wait for time reaction for up to five minutes, then turn on the spectrophotometry NOVA A-60 spectrophotometer, select an auto selector for phosphate, insert the prepared sample into a rectangular 50 mm cell and record the results indicated on display.

For activated carbon and PAC posttest sample: a sample that had been diluted was put into tubes and given the addition of activated carbon and PAC as much as 1 gram, 3 grams, 6 grams in each tube, then put into a centrifuge to be stirred with speed 400 rpm for 15 minutes. For the activated carbon sample, the solution was filtered with filter paper. In contrast, for the PAC sample, the solution was precipitated for 30 minutes for the coagulation and flocculation processes, then separate the filtrate from the sludge when finished and do the same steps as in the pretest. The research flow can be seen in Figure 1 below.

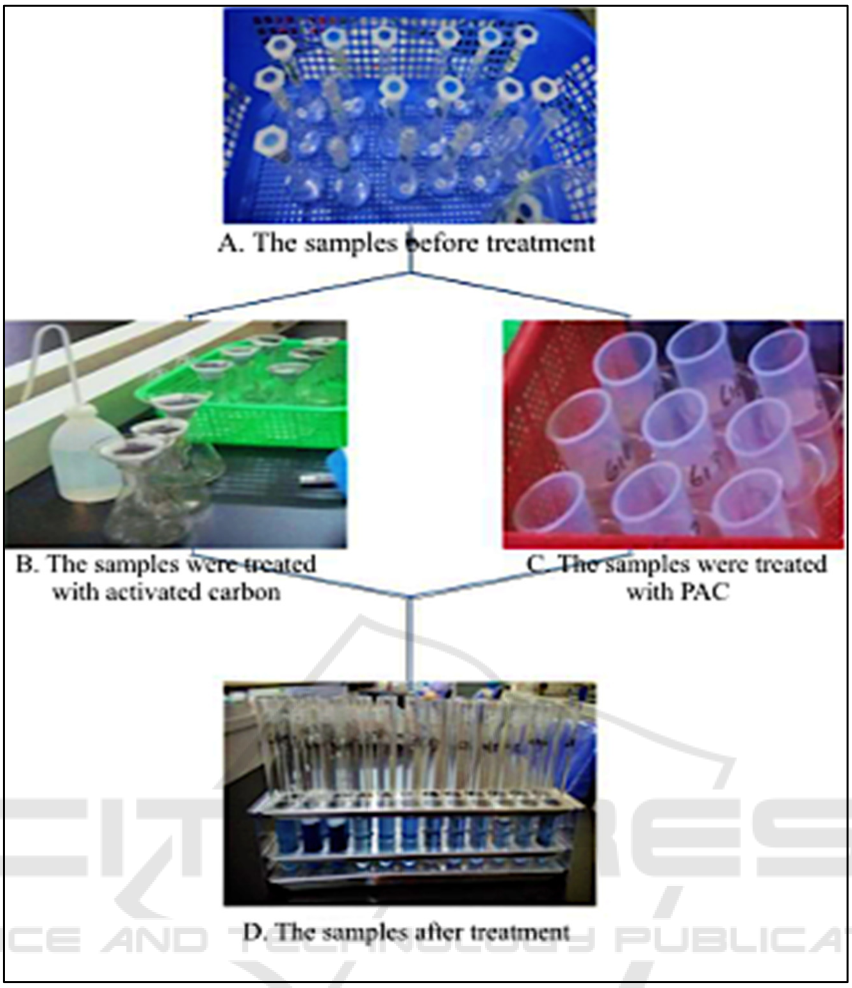

Figure 1: Research flow

Univariate analysis was used to describe each variable from the research results in a table, namely the independent variable and the dependent variable. Firstly, the bivariate approach used in this research was the Shapiro-Wilk test for the test of normality, as the number of samples was less than 50. Secondly, a T-test was conducted to determinate the differences in the efficacy of the pre-test and post-test using activated carbon and PAC (Hulu and Sinaga, 2019).

3 RESULTS AND DISCUSSION

Table 1 depicts the laboratory examination results of phosphate levels with the addition of activated carbon. From table 1, each of the highest phosphate levels in activated carbon 1 gr, 3 gr, and 6 gr occurs in the third repetition of 7.3 mg/L (38.8 %); 11.9 (65.0%) and 13.8 mg/L (75.0%). Based on the average active carbon research of 1 gr, 3 gr, 6 gr, it was obtained that the average decrease in phosphate levels as much as 12.1 mg/L (34.7 %); 7.3 mg/L (60.2%) and 5.1 mg/L (72.5%). However, that result has not been in accordance with the value of the threshold of phosphate allowed by PerMenLH No. 05 of 2014 about the standard quality of liquid waste of soap industry and detergent, namely 2 mg/L

Table 1: The results of laboratory tests on phosphate levels before and after the addition of activated carbon 1 gr, 3 gr, 6 gr.

Repetition	Activated Carbon 1 gr		Difference (mg/l)	Effectiveness (%)	NAB *
	Pre	Post			
1	18.1	12.7	5.4	29.8	2 mg/l
2	18.7	12.1	6.6	35.3	
3	18.8	11.5	7.3	38.8	
Total	55.6	36.3	19.3	104.0	
Average	18.5	12.1	6.4	34.7	
Repetition	Activated Carbon 3 gr		Difference (mg/l)	Effectiveness (%)	
	Pre	Post			
1	18.5	7.5	11.0	59.5	
2	18.0	7.9	10.1	56.1	
3	18.3	6.4	11.9	65.0	
Total	54.8	21.8	33.0	180.6	
Average	18.3	7.3	11.0	60.2	
Repetition	Activated Carbon 6 gr		Difference (mg/l)	Effectiveness (%)	
	Pre	Post			
1	18.9	5.5	13.4	70.9	
2	18.6	5.3	13.3	71.5	
3	18.4	4.6	13.8	75.0	
Total	55.9	15.4	40.5	217.4	
Average	18.6	5.1	13.5	72.5	

Table 2: The results of laboratory tests on phosphate levels before and after the addition of PAC 1 gr, 3 gr, 6 gr.

Repetition	PAC 1 gr		Difference (mg/l)	Effectiveness (%)	NAB *
	Pre	Post			
1	18.8	10.0	8.8	46.8	2 mg/l
2	18.2	9.0	9.2	50.5	
3	18.1	7.6	10.5	58.0	
Total	55.1	26.6	28.5	155.4	
Average	18.4	8.9	9.5	51.8	
Repetition	PAC 3 gr		Difference (mg/l)	Effectiveness (%)	
	Pre	Post			
1	18.3	4.6	13.7	74.9	
2	18.0	4.0	14.0	77.8	
3	18.7	1.6	17.1	91.4	
Total	55	10.2	44.8	244.1	
Average	18.3	3.4	14.9	81.4	
Repetition	PAC 6 gr		Difference (mg/l)	Effectiveness (%)	
	Pre	Post			
1	18.9	2.3	16.6	87.8	
2	18.6	2.2	16.4	88.2	
3	18.5	0.7	17.8	96.2	
Total	56	5.2	50.8	272.2	
Average	18.7	1.7	16.9	90.7	

Table 3: The result of normality test Shapiro-Wilk.

Treatment	Shapiro-Wilk		
	Statistic	Df	Sig.
Before the addition of activated carbon	.968	9	.875
After the addition of activated carbon	.875	9	.139
Before the addition of PAC	.951	9	.704
After the addition of PAC	.902	9	.263

Table 4. The result of Sample Paired T-Test.

Treatment	Mean	Difference	*p-value*
Pre-test of activated carbon	18.48	10.31	0.0001
Post-test of activated carbon	8.17		
Pre-test of PAC	18.46	13.79	0.0001
Post-test of PAC	4.67		

Table 2 indicates the laboratory examination of phosphate levels with the addition of PAC. From table 2, it is known that each of the highest decline of phosphate levels in PAC of 1 gr, 3 gr, and 6 gr occurs in the third repetition as 10.5 mg/l (58.0%); 17.1 mg/l (91.4%) and 17.8 (96.2%). The average research results of PAC of 1 gr, 3 gr, 6 gr showed a decrease in the average phosphate levels as much as 8.9 mg/L (51.8%), 3.4 mg/l (81.4%), and 1.7 mg/L (90.7%). Based on the results, it shows that PAC with dose 6 gr is already in accordance with the value of the threshold of phosphate allowed by PerMenLH No. 05 of 2014 about the standard quality of liquid waste of the soap Industry and detergent, namely 2 mg/L.

Table 3 shows the results of the Shapiro-Wilk normality test for phosphate levels of laundry liquid waste with various treatments. The p-value > 0.05 is found in the procedures, so it can be confirmed that the data distribution was normally distributed. Because the data was normally distributed, it could be continued with the Sample Paired T-Test.

Table 4 illustrates the results of the Sample Paired T-Test. It shows the pre-test and post-test on each activated carbon and PAC with treatment of 1 gr, 3 gr, 6 gr obtained a significance value (p-value) of 0.0001 (<0.05). So, Ha was accepted with the meaning that there was a difference in the average effectiveness between activated carbon and PAC to minimize phosphate levels in laundry liquid waste.

The average results of pretests and posttests of activated carbon amounted to 18,48 mg/L and 8,17 mg/l with a difference of 10.31. Meanwhile, the average result of pretests and posttests of the PAC amounted to 18.46 mg/l and 4.67 mg/l with a difference of 13.79. This suggests that PAC is more effective at lowering phosphate levels with a much higher difference than activated carbon.

This study shows that using activated carbon of 1 gr, 3 gr, and 6 gr did not indicate a phosphate decline under the quality standards established by PerMenLH No. 05 of 2014. Thus, the results are not in line with the research conducted by Majid et al. (2017) that described the initial level of laundry liquid waste phosphate before being treated was 4.98 mg / l , then after being treated with activated carbon as much as 1 gr, 2 gr, 3 g, the phosphate levels decreased to 3.35 mg / l; 2.59 mg / l; 1.89 mg / l respectively. From the result of the study, it can be concluded that the administration of 3 grams of activated carbon dosage was able to reduce the highest levels of phosphate, which was around 1.89 mg / l. This research is also not in line with the study of Utomo et al. (2018) regarding the reduction of anonic surfactant and phosphate levels in laundry wastewater. It described that the initial phosphate content before adsorption was 14.148 ppm, then after being treated with activated carbon with particle variations, namely -60, -120 and -200 mesh, it decreased. The result of lower phosphate level with activated carbon showed that the phosphate content after the treatment process was significantly reduced below the detection limit. This is because, based on the researchers' assumptions, this research was not carried out by discharging wastewater into a column whose surface contained activated carbon adsorbents. In contrast, according to Perrich in Maretha, Oktiawan and Rezagama (2014), the process of activated carbon adsorbing phosphate should be done by flowing liquid waste into the column, resulting in contact and pressure between the adsorbent with liquid waste. Not only that, but the size of activated carbon particles also affects the adsorbent process. This study did not carry out particle measurements, so the expected adsorption process was also insignificant. While activated carbon has a certain adsorption capacity. Thus, the ability of activated carbon to adsorb phosphate is limited to a value. Calculation of activated carbon adsorption capacity of various particle sizes shows that the smaller the particle size of activated carbon, the higher the adsorption capacity. This can be caused by the smaller particle size, which has a larger surface area so that more activated carbon sites or surfaces can be used as phosphates adsorbed. The process of absorption by an adsorbent is influenced by many factors and also has a specific isothermal pattern of adsorption. Factors that influence the adsorption process include the type of adsorbent, the type of substance absorbed, the surface area of the adsorbent, the concentration of the adsorbed substance (Utomo et al., 2018). PH is also considered to be an essential role during the adsorption process, which affects adsorbate species and surface charge density in adsorbents (Qu et al., 2019).

Because of these factors, each adsorbent that absorbs one substance with another substance will not have the same pattern of adsorption isotherms. This shows that the adsorption process that occurs between activated carbon and phosphate is more physical, where the bonds formed are physical bonds with there being more than one surface layer (multilayer). Besides, despite being able to create a multilayer layer on the surface of activated carbon, the anionic surfactant adsorption capacity also remains influenced by the surface area of activated carbon (Kurniyati, Sumarni and Latifah, 2015). Meanwhile, after the addition of 1 gr, 3 gr, and 6 gr PAC, there was a significant decrease in the 6 gr PAC dose that was 1.7 mg / l (90.7%). This shows that PAC is more effective in reducing phosphate levels until it meets the established quality standard of 2 mg / l.

This study is in line with the results of the research by Andriani, Darundiati and Dangiran (2017) that showed that the phosphate content in the effluent liquid waste samples before treatment was 2.92 mg / l; 3.46 mg / l; 3.10 mg / l; 3.17 mg / l; and 3.59 mg / l. However, after being given the addition of PAC treatment with each dose of 0.3 gr; 0.4 gr; 0.5 gr; 0.6 gr; and 0.7 gr the phosphate level decreased, namely 1.83 mg / l (43.69%), 1.48 mg / l (54.46%), 1.43 mg / l (56%), 1.34 mg / l (58.77%) and 1.08 mg / l (66.77%). From the results of this study, it can be concluded that the administration of PAC has been effective in reducing phosphate levels so that it is below the quality standard of the Central Java Regional Regulation, which is 2 mg / l.

The low level of phosphate produced after the addition of PAC shows that PAC can reduce the level of phosphate, which is under the acceptable threshold of the environmental quality standards. The addition of PAC coagulants to the waste causes colloids and other suspended particles to combine to form heavy particles (floc). The coagulation process can remove contaminants such as solid impurities that cannot be removed by ordinary filtration. Adding PAC coagulant to the waste will neutralize negatively charged particles. That is because PAC has a high positive charge and can bind colloids strongly to form aggregates (Rohaeti, Febriyanti and Batubara, 2010).

The addition of PAC coagulants causes elements in liquid waste to experience instability. When the PAC coagulant is added to the wastewater, PAC will dissociate and the metal ions will undergo hydrolysis and produce hydroxy complex ions, which are positively charged so that they are adsorbed on the negative colloidal surface. PAC has positive charge characteristics and can bind aggregates tightly so that it can attract and combine suspended particles in the liquid waste (Rohaeti, Febriyanti and Batubara, 2010).

4 CONCLUSIONS

The average phosphate content before the study was 18.4 mg / l and still exceeds the quality standard set in PerMenLH No. 05 of 2014. The addition of a 6 gr PAC dose is more effective in reducing phosphate levels in laundry liquid waste with an average decrease amounted to 1.7 mg / l (90.7%). It was below the quality standard of PerMenLH No.05 of 2014 concerning Wastewater Quality Standards for Business Activities of Soap, Detergent, and Vegetable Oil Products Industry that is equal to 2 mg / l. So it is recommended for the laundry service industry to treat the liquid waste first before being discharged into water bodies using a 6 gr PAC dose. It is recommended for subsequent researchers to use other coagulants such as alum to compare with the PAC so that they can measure which one is more effective in reducing phosphate liquid waste levels in the laundry area, whether using an effective dose of 6 grams or more.

However, this study has limitations, which are: the study only examined one laundry center and only checked phosphate levels with two comparison media. Therefore, future studies can involve more industrial laundry premises and use more than two coagulants or adsorbents that can be compared with a larger number of samples.

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