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Application of Alum and Cassava Peel Starch (CPS) as Dual Coagulant in Surface Water

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Abstract: In recent decades, surface water is increasingly threatened due to rapid development. The overdosing chemical coagulants in coagulation and flocculation has led to environmental problems and harmful to human health. Therefore, cassava peel starch (CPS) has been proposed as potential natural coagulant aid to remove turbidity, total suspended solids (TSS) and chemical oxygen demand (COD) concentration by dual coagulant in coagulation and flocculation process. The constant performances of jar tests were at 200 rpm for 1 minutes, 100 rpm for 2 minutes of rapid mixing and 25 rpm for 30 minutes of slow mixing to promote floc formation. According to the result in this study, water quality of raw water collected from Parit Raja water treatment plant, Johor is classified as Class I to Class IIA. The mean values of temperature, turbidity, TSS and COD are 26.91 ˚C, 13.57 NTU (IIA), 8.89 mg/L (Class I) and 18.78 mg/L (Class I) respectively. Several batches of Jar tests have been conducted for optimization study of alum and cassava peel starch in context of pH value and coagulant dosage. In accordance to the findings, the optimal pH value for alum with CPS is pH 8 while the optimal coagulant dosage value for alum with CPS is 75:25 (11.25 mg/L of alum solution and 25 mg/L of CPS solution) was obtained as the percentages of removal of turbidity, TSS and COD values were higher than treatment using alum alone (92.41%, 8.75% and 94.68%). The result of the present study is reflected that CPS as natural coagulant is effective to facilitate the removals of turbidity, TSS and COD in surface water.

Keywords: Water Treatment Plant, Coagulation and Flocculation, Cassava Peel Starch, Coagulant Aid.

1. Introduction

Recently, there are numerous issues regarding to contaminated rivers which include high level of turbidity, suspended solids and chemical oxygen demand (COD). These major pollutants not only harmful to human health but also significantly affect aquatic life [1,2,3]. According to [4], the increasing

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human population in Malaysia at approximately 32.6 million people in 2019 will requires high demand of clean water. Cost of water to be treated becoming increases due to deterioration of water quality. In order to treat the contaminated water, high dosage of inorganic coagulants is used. This leads to high aluminium content in treated water due to formation of secondary byproduct from chemical coagulants. Furthermore, it tends to increase the sludge production that need intensive treatment to dispose it along with Alzheimer disease when the consumers consume the treated drinking water of high aluminium content [4,5].

Demand of natural coagulants in water treatment plants have caused rise up due to its advantages which are cheaper, biodegradable and safe to human health. Based on previous research on organic coagulants, orange peel able to remove 97% of turbidity from dairy wastewater [6], *Carica papaya* tends to remove 90% of turbidity in surface water [7] while *Moringa Oleifera* seed results to remove total suspended solid in coffee fermented wastewater at 54% [8]. These efforts show that natural coagulants have high potential to be employed as effective water treatment agent in coagulation and flocculation process.

In Malaysia, cassava peels are agricultural waste obtained from cassava chips production. From waste, cassava peel is potentially to be developed to become effective natural coagulant agent. Other than that, it will be other alternatives for local food industries to gain additional income during current COVID pandemic. Polysaccharides in cassava peels bring lots of benefits as coagulant agent which starch, pectin and cellulose have potential for removal of organic and inorganic pollutants [9,10]. Moreover, cassava peels have high carbohydrate content which easier the floc to settle down due to the fairly shear stable. Based on these interesting properties, the usage of high dosage of alum as main coagulant is expected to be potentially reduced when used in tandemly with cassava peel starch as dual coagulant.

Coagulation and flocculation process is conventional treatment that used to treat surface water. Surface water is water that collects on the top of surface in the water treatment plant. Generally, surface water not clean and safe enough to be consumed without any appropriate treatment [11].Therefore, surface water treatment is crucial process to ensure clean water supply for public consumption. As illustrated in Figure 1.1, flocculation and coagulation process neutralize the particles with negative charges. This process is easy to monitor yet low energy consume method to remove turbidity and suspended solids [12]. In coagulation process, there are two types of coagulants will be used either single or dual coagulants. Dual coagulants are generally deployed specially to treat highly polluted waters. Dual coagulants are combination of primary coagulant which is in the form of metallic salts with secondary coagulant which is in the form of synthetic or natural polymers [13,14]There are lots types of coagulants in water treatment such as aluminium sulphate, aluminium chloride, sodium aluminate, ferric sulphate, ferric chloride and ferric chloride sulphate. The most common primary coagulant agents used in water treatment is aluminium sulphate or alum ($Al_2\ (SO_4)_3.18H_20$). Alum is positive charged that tends to attract the negative charge ions to neutralize it and will coagulate the small particles into bigger size in the form of floc. In that way, it will easier to trap at the filter during flocculation and coagulation process. However, past research stated that the effects of overdose of alum tends to reduce the pH of water [15] and give bad effects of long-term health to consumers such as Alzheimer’s disease [3,5].

Regarding to priority towards environmental concerns, natural coagulant as secondary coagulant in term of dual coagulant is the best option. Natural coagulants are capable to remove turbidity [10], suspended solid [8] and COD concentration [16;17,18] in surface water. It will improve the performance of coagulation process and reduce the usage of chemical coagulant. From the past research, some examples of natural coagulants that have been researched are rice starch [19,20] and corn starch [21].

The objectives of this study are to characterize raw surface water from intake tank of Parit Raja water treatment plant and to determine the optimization of coagulation and flocculation process for turbidity , total suspended solids (TSS) and chemical oxygen demand (COD) removals in surface water.

2. Materials and Methods

2.1 Sampling of Surface Water

Surface water was collected from raw water inlet tank of Parit Raja Water Treatment Plant, Johor, Malaysia. Water from pond nearby and rain run offs varies widely in its turbidity, suspended solids and chemical oxygen demand, COD concentration. The sampling method has been used to collect 10 liter of water samples in 1000mL of HDPE bottles. Before that, all sampling bottles need to rinsed with nitric acid in order to ensure the sampling bottles are clean from any contaminants. The sampling bottles were fully filled in order to avoid the present of air bubbles or any organic matters in the bottles. Next, the water samples were stored and transported to the laboratory in a cool box immediately. This is an important precaution step due to lowering the activities of chemical and biological reaction to happen. The temperature of water samples was brought back into room temperature prior to analysis [23]. The sample of surface water was analyzed at the laboratory of Environmental Engineering, Universiti Tun Hussein Onn Malaysia.

2.2 Preparation of Cassava Peel Starch (CPS) as Natural Coagulant Aid

The waste of cassava peels was collected at a local factory, Md. Shah & Asiah Kripeks, Parit Raja Darat, Johor, Malaysia. The process of starch extraction from cassava peels were done manually by washing, blend, filtering, evaporating and store it at dry condition. Firstly, the flesh cassava peels were selected and cleaned it with tap water repeatedly. This process helps to remove any unwanted impurities. Next, the peels were cut into small pieces [22]. CPS were washed and rinsed with tap water before blend it for 5 minutes. 100mL of distilled water must be added to suspended 50g of peels before pulverization in a domestic blender [23]. Then, the pulp was suspended in 1 liter of distilled water and stirred continuously for 2 minutes. For filtering process, the suspension was filtered by using double fold muslin cloth. After that, the filtrate was stand for 2 hours to allow the gravitational sedimentation process before discarding the top liquid. The sediment at filter muslin cloth were collected and need to dried up through natural sunlight for at least 24 hours so, the sediment was at dry condition as the moisture content has been removed. Finally, the CPS powder were be kept in air tight plastic container to keep it dry for further experimental use.

2.3 Preparation of Cassava Peel Starch (CPS) Stock Solution

1000mg/L of CPS stock solution were prepared for this experiment. The solution has been added by 1g of CPS powder and 1L of distilled water and this solution was stirred continuously for 60 minutes to complete the mixing process. According to [24], CPS stock solution was diluted with distilled water to intended concentration prior to coagulation test.

2.4 Preparation of Alum Stock Solution

10g of alum was added with 1L of distilled water. Alum stock solution was prepared by following the same procedure of CPS stock solution[24]

2.5 Optimization Study of Coagulation and Flocculation using Jar Test

For this study, jar tests were done to analysis the effectiveness of CPS as natural coagulant to remove the parameters of turbidity and total suspended solids in surface water. For jar test experiment, the apparatus has been setup up with standard flocculator with 6 paddles and six 1L volume of beakers that filled with water samples from Parit Raja water treatment plant. Before start the experiment of jar test, the pH of raw water was recorded and done the pH adjustment by adding 0.1M hydrochloric acid and 0.1M of sodium hydroxide. Jar tests were conducted with 2 sets of experimental conditions:

i. Alum as coagulant

ii. Alum and CPS as dual coagulant

The experiments were repeatedly for three times in order to get the average value. Table 1 and Table 2 shows the plan of optimization study for this present study and details of experimental conditions for this present study.

Table 1: The optimization study plan for present study.

List	Objective	Experiment
Preliminary study	1. To characterize raw surface water from intake tank of Parit Raja water treatment plant.	Characteristic of raw surface water: a) COD b) TSS c) pH d) Turbidity
	2. To optimize working conditions for the removal of turbidity, total suspended solids (TSS) and chemical oxygen demand (COD) in surface water.	Analysis by using Jar test: a) Turbidity b) TSS
		Analysis by using COD test: a) COD value for water sample

Table 2: Details of the coagulation and flocculation study in experimental conditions.

No	Coagulant	pH	Coagulant Dosage (mg/L)		
1	Alum	4,5,6,7,8,9	5,10,15,20,25,30		
2	CPS	4,5,6,7,8,9	100,200,300,400,500,600		
3	Alum-CPS	4,5,6,7,8,9	Effective Ratio	Alum	CPS
			100% : 100%	15.00	100.00
			100% : 0%	15.00	0.00
			75% : 25%	11.25	25.00
			50% : 50%	7.50	50.00
			25% : 75%	3.75	75.00
			0% :100%	0.00	100.00

3. Results and Discussion

3.1 Characterization of Parit Raja Water Treatment Plant

The values of raw surface water at Parit Raja water treatment plant were obtained during rainy season of December. The climate changes lead to the dilution of each concentration of parameter to be conducted. The range of turbidity values are 6.88 NTU to 7.07 NTU. This can be classified as Class IIA, as the conventional treatment is required according to Table 2.5, Interim National Water Quality Standards ,INWQS. Furthermore, the value of COD and TSS concentration are 18.78 mg./L and 8.89 mg/L which are classified in Class I. the range of water temperature is low as the water samples were collected in the early morning. The average of pH water is 6.96 which is acidic but near to neutral condition. In addition, the mean of BOD reading in 5 days is 44.63 mg/L which is at Class V. Besides, for values of metals content in raw water, ferum and manganese values has been obtained. The mean value of ferum and manganese are 0.67 mg/L and 0.07 mg/L. These values are classified as Class I. Next, the concentration of colour is 52.89 ADMI and classified in Class IIA. Overall, the water quality of surface water at Parit Raja water treatment plant is Class I to Class IIA as illustrated in Table 3.

Table 3: Raw water characteristics of Parit Raja Water Treatment Plant in December 2021

No	Parameter	Unit	Min – Max			Mean	Standard Deviation	INWQS Class	Drinking Water Quality Standard
1	Temperature	°C	25.40	-	28.30	26.91	1.45	-	-
2	pH	-	6.88	-	7.07	6.96	0.10	I	5.5 – 9
3	Turbidity	NTU	11.00	-	16.55	13.57	2.80	IIA	1000
4	COD	mg/L	13.33	-	22.67	18.78	1.17	I	10
5	TSS	mg/L	7.00	-	11.00	8.89	2.01	I	1 500
6	BOD5	mg/L	16.88	-	69.30	44.63	26.35	V	6
7	Ammonia	mg/L	0.07	-	0.14	0.11	0.04	IIA	1.5
8	Ferum, Fe	mg/L	0.66	-	0.69	0.67	0.02	I	1
9	Manganese, Mn	mg/L	0.06	-	0.08	0.07	0.02	I	0.2
10	Colour	ADMI	50.00	-	56.00	52.89	3.01	IIA	300 TCU

3.2 Optimization of Coagulant Dosage

Jar test is carried out to optimize the coagulant dosage of alum as single coagulant and alum with CPS as dual coagulant. This study also to examine and analysis the effect of coagulant dosage to the treated water, where the change in the value of parameters of turbidity, total suspended solids and COD. The results were shown in Figure 1. In order to optimize the effect of alum dosage, the constant working conditions were applied as pH water is 8 (Figure 1), the settling time is 30 minutes, the minimum and maximum of mixing speed are at 200 rpm (1 minute), 100 rpm (2 minutes) and 25 rpm (30 minutes)[18].

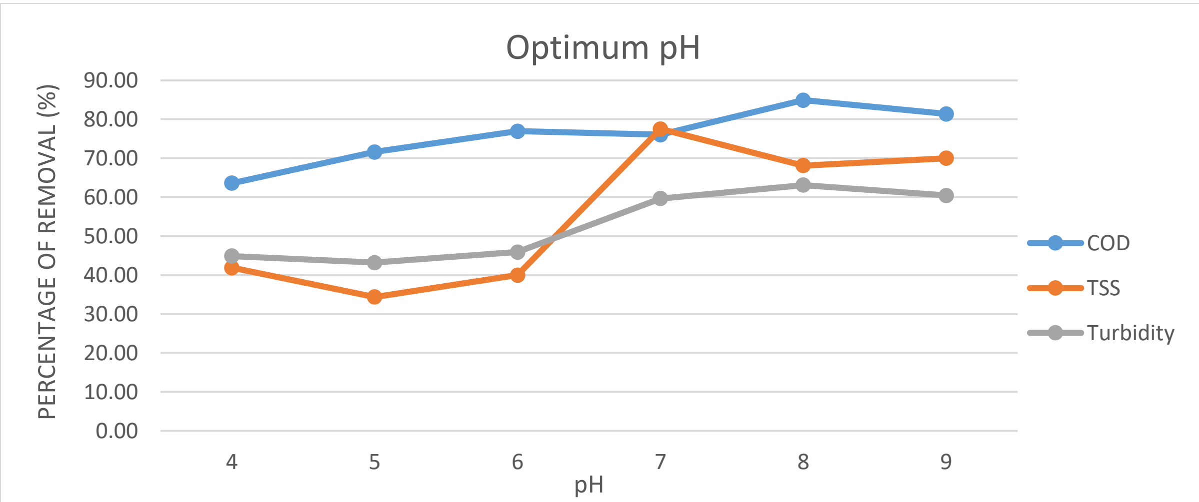

Figure 1: Graph of determination of the optimal pH as to analysis the effect of alum dosage.

Table 4: Percentage of removal in each parameter of treated water.

		pH					
	Unit	4	5	6	7	8	9
Turbidity	%	44.90	43.20	45.91	59.64	63.12	60.44
TSS	%	41.88	34.38	40.01	77.50	68.13	70.00
COD	%	63.61	71.60	76.93	76.04	84.91	81.36
Average		50.13	49.73	54.28	71.06	72.05	70.60

3.2.1 Effect of Alum Dosage

Figure 2 shows that the jar test experiments condition of lowest and highest dosage of alum for to treat water are 5 mg/L and 30 mg/L. The percentage of turbidity removal increases rapidly from 28.89% (5 mg/L) to 73.18% (15 mg/L). The reading started to decreases at 70.52% (20 mg/L) and reach to the highest percentage of turbidity removal, 75.61 % (25 mg/L). At a dosage rate of 30 mg/L, the percentage of turbidity removal turn to decreases to 68.53%. This can be concluded that the optimum coagulant dosage of alum is at 15 mg/L. This is because at dosage of 15mg/L, the graph in Figure 2 obtained the reading of effectiveness of turbidity removal started to reach at the best condition without lowering the percentage of turbidity removal. Based on the previous study, turbidity reversal due to overdose alum usage. Aggregation occurs when the particles become disrupted as overdose coagulant causes charge reversal, and particles begin to restructure. As a result, when the coagulant dose is higher than optimum coagulant dose and reduce turbidity removal. [1,25].

With alum dosage ranging from 5mg/L to 30 mg/L, the TSS removal percentage level was increases from 32.51% to the highest, 88.75%. Apart from that, the recommended dosages for removing the highest TSS with alum alone (88.75%) were 15, 25 and 30 mg/L, respectively. According to [26],the highest percentages removal of TSS has been achieved to treat agro-industrial wastewater at two different alum dosage at 0.3 and 2.0 g/L (86.3%).

It was observed that the best performance of alum to remove COD is at dosage rate of 15 mg/L (94.68%). Based on the graph in Figure 4.3, the percentage removal increases from 78.70% to the highest, 94.68% at 15 mg/L. However, the percentage removal decreases from 94.68% (15 mg/L) to 84.03% (20 mg/L and 25 mg/L respectively). The COD removal turn out increases back from 84.03% (20 and 25 mg/L) to 89.35% (30 mg/L) of alum dosage. Besides, [27] stated that the optimal dosage affected to the results of COD removal. This can be determined that the uneven result of COD removal in treated water. On the whole, according to the result of turbidity, TSS and COD removal, 15 mg/L of alum dosage will be determined as the optimal alum dosage in this study.

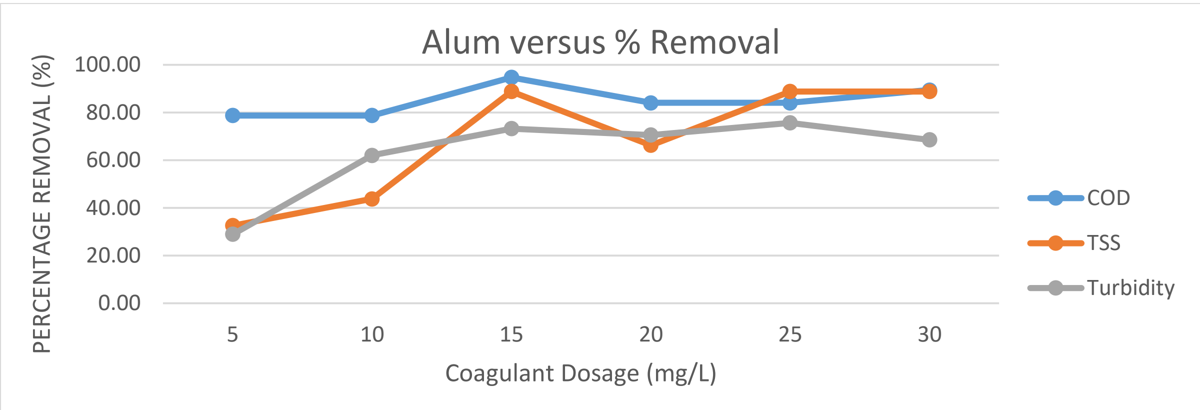

Figure 2: Removal percentages of turbidity, COD and TSS for different alum dosages at pH 8.

3.2.2 Effect of Alum and Cassava Peel Starch (CPS) Dosage

In order to optimise the effect of alum and CPS dosage, the constant working conditions were applied as pH water is 8 (Figure 1), the settling time is 30 minutes, the minimum and maximum of mixing speed are at 200 rpm (1 minute), 100 rpm (2 minutes) and 25 rpm (30 minutes) [18]. To recap the determination of optimal alum dosage, the result has been recorded that 100% of alum dosage is equal to 15 mg/L. For the optimal dosage of CPS, based on the previous study, 100% of CPS dosage is equal to 100 mg/L [16,18,23].

According to the results of the jar test in pH 8 as shown in Figure 3, the highest percentage of turbidity removal is 92.41% at ratio of 75:25 (11.25 mg/L of alum solution and 25 mg/L of CPS solution). By using the alum alone at ratio of 100:0 (15mg/L of alum solution), the result is 77.44% which is 14.97% lower than ratio of 75:25. This can be deducted as the result to remove turbidity has been improved with the combination of alum and CPS as dual coagulant in this study [14,18,23]. Furthermore, when the CPS is used alone to remove the turbidity, the result of percentage of turbidity removal is 58.59% which is 12.23% lower from result of only alum dosage used. Based on the past study, CPS has a lot of potential as coagulant aid in removing turbidity, TSS and COD [2,16,23]. This can be a great solution to the issue of overdosing alum usage in water treatment.

Figure 3 shows that the highest percentage of TSS removal is 94.68%. The only dosage ratio of alum and cps that has been resulted the lowest performance is 25:75 (3.7 mg/L of alum solution and 75 mg/L of CPS solution) with 62.73% only. Furthermore, the highest percentage of COD removal is 94.68%. all the jar test series has been achieved the highest COD removal except to the ratio of 25:75 (3.7 mg/L of alum solution and 75 mg/L of CPS solution). In this case, the alum dosage is 3.7 mg/L which is lower than the optimal alum dosage, 15 mg/L. Nevertheless, this can be shown that the best ratio of dosage rate is 75:25 (11.25 mg/L of alum and 25 mg/L of CPS) with the highest percentage of turbidity, TSS and COD concentrations (92.41%,43.76% and 94.688%).

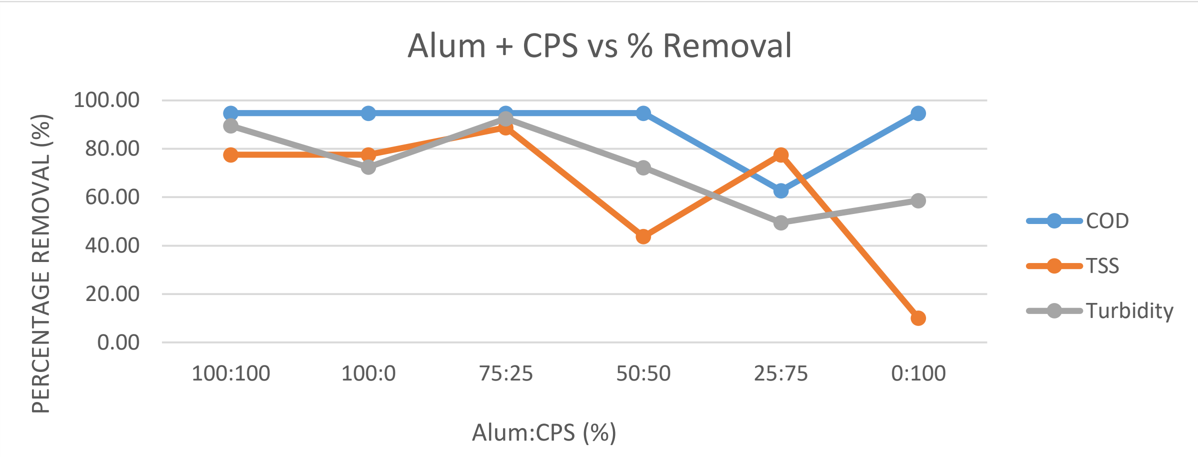

Figure 3: Removal percentages of turbidity, COD and TSS with alum and CPS dosage

3.3 Optimization of pH

In order to optimize the effect of pH water, the constant working conditions were applied as coagulant dosage of alum is 15 mg/L (Figure 4) and for dual coagulant dosage is 75:25 (Figure 5), the settling time is 30 minutes, the minimum and maximum of mixing speed are at 200 rpm (1 minute), 100 rpm (2 minutes) and 25 rpm (30 minutes) [18].

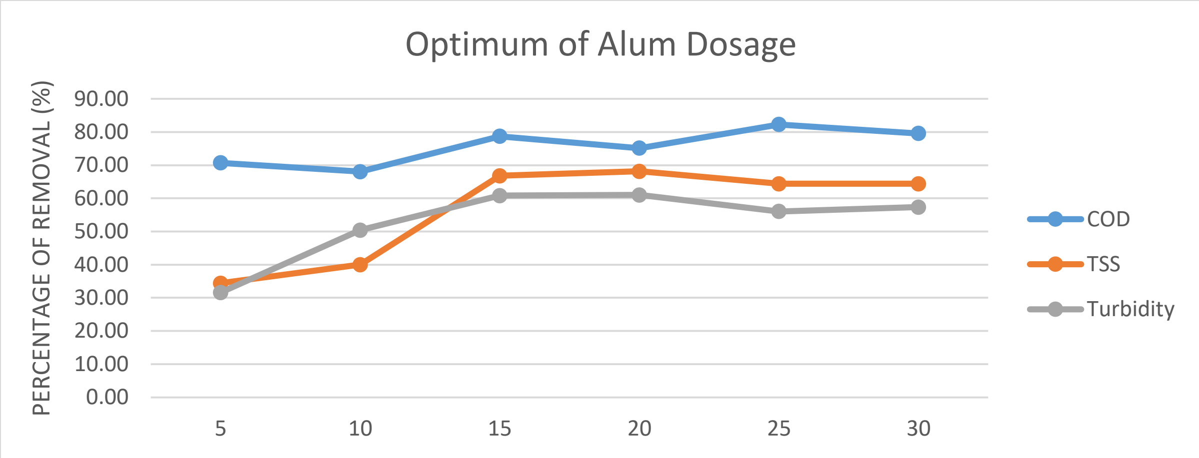

Figure 4: Graph of determination of the optimal alum dosage due to analysis the effect of pH.

Table 5: Percentage of removal in each parameter of treated water by alum dosage.

		Coagulant Dosage					
	Unit	5	10	15	20	25	30
Turbidity	%	31.60	50.39	60.80	61.02	56.04	57.36
TSS	%	34.38	40.01	66.80	68.13	64.38	64.38
COD	%	70.71	68.05	78.70	75.15	82.25	79.59
Average		45.57	52.82	68.77	68.10	67.56	67.11

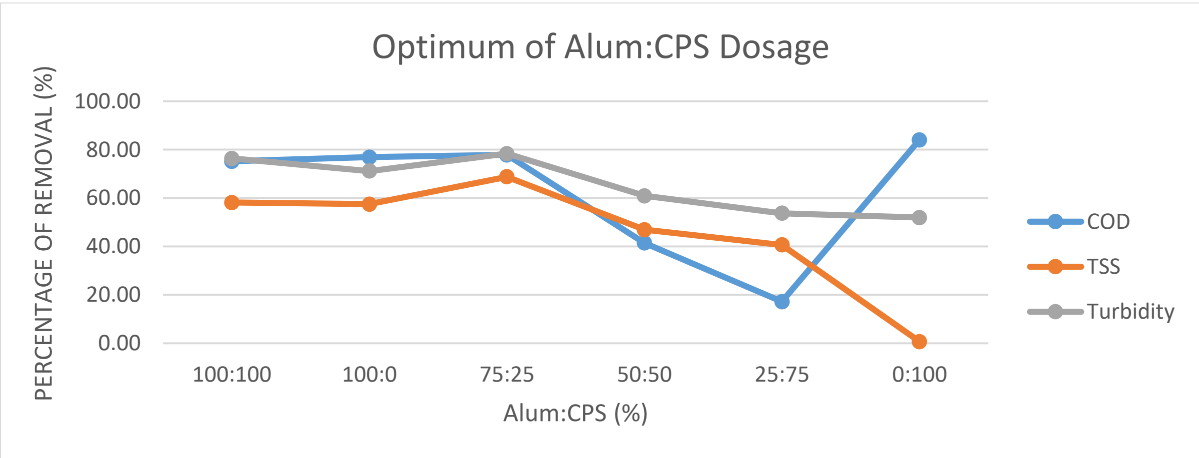

Figure 5: Graph of determination of the optimal alum : CPS dosage due to analysis the effect of pH.

Table 6: Percentage of removal in each parameter of treated water by alum : CPS dosage.

		Coagulant Dosage					
	Unit	100:100	100:0	75:25	50:50	25:75	0:100
Turbidity	%	76.38	71.15	78.36	60.93	53.73	51.89
TSS	%	58.14	57.50	68.75	46.89	40.63	0.64
COD	%	75.15	76.93	77.81	41.43	17.15	84.03
Average		69.89	68.52	74.97	49.75	25.74	45.52

3.3.1 Effect of pH on Turbidity Removal.

The effect of pH of treated water was considered by applying the optimum dosage of each alum and CPS concentration. Based on the Figure 6, it was observed that between the varied pH 4 to pH 9 of treated water samples, it showed that pH 8 of water samples is the highest removal of turbidity by single coagulant, alum (73.18%) while dual coagulant, alum with CPS (92.41%). This differences of 19.23% lead to influence the effectiveness of turbidity removal in water treatment. This can be shown that CPS has high potential as coagulant aid with alum to treat water better. In reference to past research, the effectiveness of turbidity removal increases with the present of CPS to remove the turbidity at pH 9 [17,18].

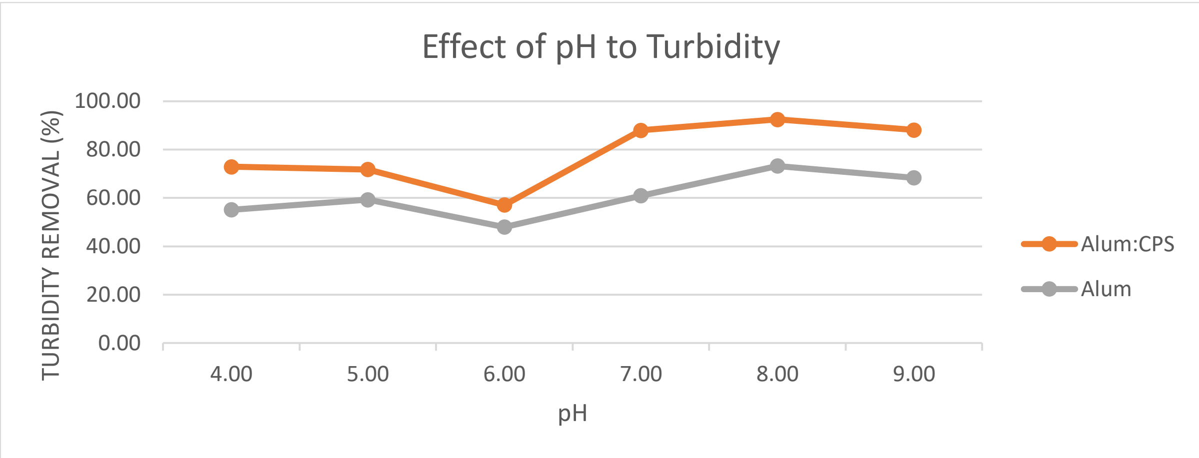

Figure 6: Removal percentages of turbidity for different pH.

3.3.2 Effect of pH on TSS Removal

Referring to Figure 7, the highest of TSS removal percentage is 88.75% at pH 7 and pH 8 for both proposed coagulants. Differ from result of alum dosage at pH 4, the percentage removal of TSS is 21.26% while using alum with CPS dosage, the result is 55.01%. In general, the difference of 33.75% tend to state that the effectiveness of alum with CPS is higher than alum alone at pH 4. In a way, alum with CPS dosage shown that the TSS removal drop from 55.01% (pH 4 and pH 5) to 47.47% (pH 6). Despite, the percentage of removal of TSS grow up to the highest, 88.75% (pH 7 and pH 8) and started to drop to 77.50% at pH 9. As specified in previous study, when the pH increases, the TSS removal increases at certain point [18,23].

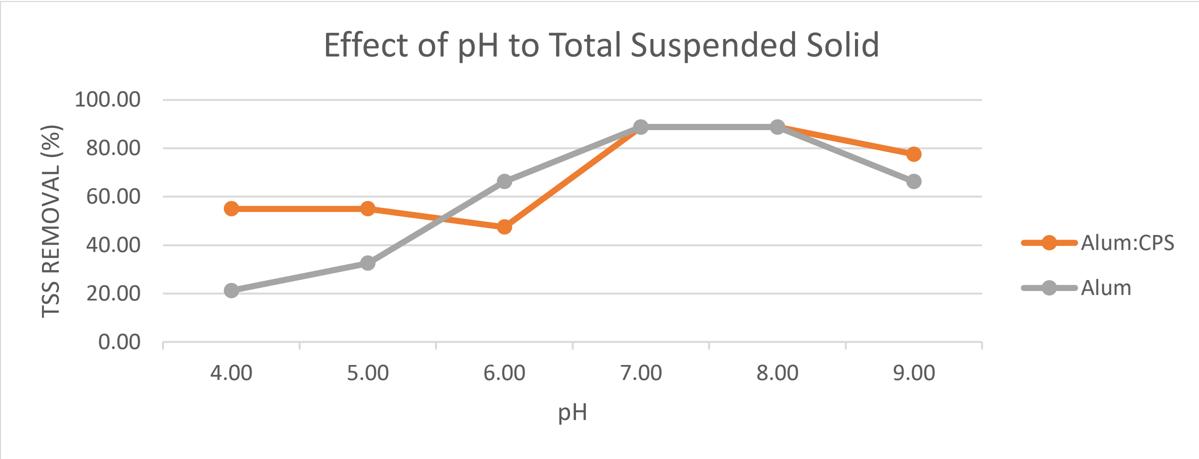

Figure 7: Removal percentages of TSS for different pH.

3.3.3 Effect of pH on COD Removal

As specified by Figure 8, at pH 4, the percentage removal risen up from 46.75% to 73.38% at pH 5. However, the percentage removal decreases from 73.38% (pH 5) to the highest, 100% (pH 8). Then, COD removal turn out to drop from 100% (pH 7) to 94.68% (at pH 9). Referring to Alum with CPS dosage, the highest percentage of COD removal is 94.68%., all the pH of 4,6,7,8 this study except for pH 5 get the best result to reduce the COD concentration of treated water. It was obtained that the best performance of alum to remove COD is at pH 8 (100%) while for dual coagulant is at pH4, pH 6, pH 7, pH 8 and pH 9 respectively (94.68%). The difference of COD percentage removal by alum and dual coagulant, alum with CPS is 5.32%. In addition, the optimal dosage influence to the results of COD removal. This can be determined that the imbalance result of COD removal in treated water [27].

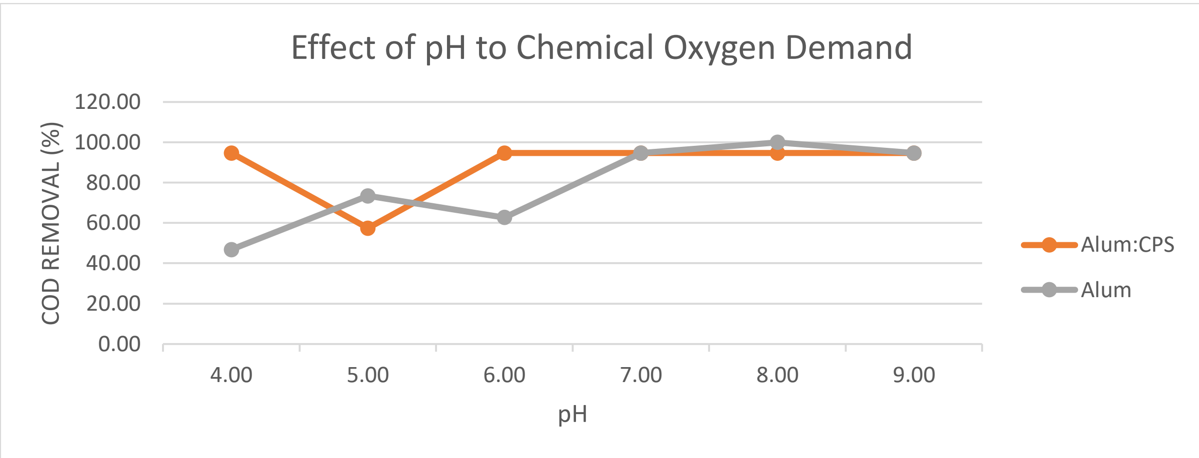

Figure 8: Removal percentages of COD for different pH.

4. Conclusion

This study was conducted to prove that natural coagulant of CPS able to perform good result along to reduce chemical coagulant usage like alum in coagulation and flocculation. The outcomes have been achieved to remove turbidity , total suspended solids (TSS) and chemical oxygen demand (COD) content in surface water. Based on the results and discussion, the optimal coagulant dosage value for alum with CPS is 75:25 (11.25 mg/L of alum solution and 25 mg/L of CPS solution).The percentages of removal of turbidity, TSS and COD values were higher than used alum alone (92.41%, 88.75% and 94.68%) with the reduction of alum usage involved to treat water samples. Besides, the optimal pH value for alum with CPS is pH 8. The percentages of removal of turbidity, TSS and COD values were higher than used alum alone (92.41%, 88.75% and 94.68%). This study shown that cassava peel is harmless, simple to use and high effective of natural coagulant as a coagulant aid in water treatment.

The recommendations towards the determination of optimization pH and coagulant dosage due to the application of CPS as coagulant aid for future uses and further study purposes have been promoted as follows :

1. To determine the water characteristics of surface water in dry season in order to prevent the dilution of concentration of parameter in rainy season can be considered.
2. To conduct the coagulation-flocculation process by treating the industrial wastewater in order to produce better result on the effectiveness of dual coagulant, alum with natural coagulant (CPS) to remove turbidity, TSS and COD.
3. In order to produce better result of percentage of removal turbidity, TSS and COD, the settling time for jar test can be considered which has longer time for floc formation.
4. Beside these, a wide variety of water samples need to be examined to figure out the effectiveness of dual coagulants for water treatment.

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