Turbidity, COD and Total Suspended Solid Removal: Application of Natural Coagulant Cassava Peel Starch

Nur Shahirah Abd Rahim, Norzila Othman, Syarifah Nur Fahirah, Syazwani Mohd Asharuddin, Marlinda Abdul Malek

Abstract: ***Considering techno-financial oblige, cassava peel (CP) that is effectively accessible mechanical waste is concentrated to assess its appropriateness to be chosen as coagulant help for the water treatment framework. The process called coagulation and flocculation is the generation of consumable water from most raw water sources generally incorporates. The most well-known coagulant used in water treatment are aluminium salts, ferric salts and synthetic polymers. These coagulants are frequently costly and can hardly afford the costs of imported chemicals. Considering techno-economic constrain, cassava peel (CP) that is effectively accessible industrial waste is concentrated to assess its appropriateness to be chosen as coagulant aid for water treatment system. This aim for characterize cassava peel and to optimize coagulation and flocculation process using alum, CPS and alum : CPS. There are two types of equipment analysis involve to characterization the cassava peel namely scanning electron microscope (SEM-EDX) equipped with energy dispersive X-ray spectrometer (EDX) and X-ray fluorescence (XRF) spectrometry. SEM-EDX micrograph had shown that the surface of the cassava peel samples was secured with smooth and globular in formed of bound a starch granule. The CP samples contain Fe^2O^3 and Al^2O^3 were analysis by XRF spectrometry indicated that which might contribute to its coagulation ability. The water samples used was collected at the water intake from Sembrong Dam. The raw water sample was characterized before the process of jar test. Jar test experiment was carried out by using alum, cassava peel starch and cassava peel + alum. The laboratory analysis was carried on turbidity, total suspended solid and COD removal. Recommended conditions (initial pH 9, 70 : 30 % of alum : CPS, and 60 min settling time) allowed Cassava peel and alum removed high turbidity, total suspended solid and chemical oxygen demand up to 90.32%, 89.86% and 18.87%, respectively. The effectiveness of cassava peel as coagulant aid was investigated from floc analysis. Besides that, based on the results with using SEM analysis, the images showed that the combination of alum +CPS was more compact and this can make denser because of the bridging of the particles that easy the floc to settle down. This study proved the use of natural coagulant from cassava peel as an alternative coagulant aid to reduce the usage of chemical coagulants.***

Keywords : Water treatment system, coagulation and flocculation, cassava peel starch, coagulant aid.

I. INTRODUCTION

Water is a vital resource but presents as a worrisome depletion in recent times. It recovers the state of seas and oceans, rivers, lakes and forests which turn into a piece of the personality of situations and scenes and of central significance for the advancement of biological communities and human life [1]. One of the fundamental factors that are engaged with the human improvement considering is water question which effect on human lives [2]. The measure of necessity for goof drinking water quality is expanding, as the non-contaminated water assets are ceaselessly diminishing. However, the creating populace measure growing the lifestyle, ecological change, industrialization, agribusiness and urbanization has set off the decrease in clean water holds worldwide since water has been seen as an unending not too bad [3]. Moreover, there are two type of water sources used regularly in the treatment of water supply. The two type of water sources are groundwater and surface water. Surface water is the important sources for further water treatment. Surface water is from rivers, lakes and reservoirs. Characteristic of the surface water includes of variable composition, low mineral content, high turbidity, color, low dissolved oxygen, low hardness, taste and odor. Satisfactory water treatment and sanitation to treat water sources are fundamental to evacuate turbidity, pollutions and other pathogenic microbes which can be guided through the process of coagulation and flocculation [3].

Coagulant assumes an essential part in ranges of water treatment. Coagulant of aluminum sulfate or alum ($Al_2(SO_4).18H_2O$) is usually types of coagulant used in water treatment plant, where alum will be added into water to form aluminum hydroxide and the colloidal in the water are removed by charge neutralization [4].

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However, a inorganic coagulant that are utilized broadly have impediments, for example, substantial dose, low impact and hurtful to human body in the meantime inorganic coagulant has burdens of high cost, toxicity and the application are limited . The function of the coagulant is to attract the negative charge to occur the floc for produce the clean water.

Besides that, high dosage of alum will give bad impact to the consumer and the effect may cause Alzheimer's disease based on several researchers [5].

In certain cases, coagulant is applied together with coagulant aid to increase the performance [6]. Various natural coagulant aids were performed in water treatment [7]. An option for more environmental and less hazard to the consumer is using the natural coagulant. The natural coagulant is the best alternative method for removal turbidity and also safer for human life, biodegradable, practical, non-dangerous, non-destructive and unlikely to create water with extreme pH. An example is using coagulant aid in form of natural plant base. An example of natural coagulant based on the previous study is Moringa oleifera seeds [8], CicerAretinum [9] and Cactus [10]. Accordingly, those natural coagulant make them a promising option towards decreasing dosage of chemical coagulant that can improve and decrease turbidity, TSS and COD in water.

The benefits of natural polymers are biodegradable, cheap and their shelf life depends on their biodegradability [11] and can be used as a creative alternative with use waste. Cassava is an alternative for coagulation and flocculation process such as natural coagulant. The type of natural coagulant for cassava peel are classified in waste materials as a low cost to remove pollutants from water [12]. Cassava contains a source of carbohydrate, riboflavin, thiamin, and nicotinic acid [13]. Furthermore, high carbohydrate, make floc easy to settle down because of the fairly shear stable. Cassava starch contains two major molecular components, which are amylase and amylopectin. The molecular components amylose and amylopectin are formed in semi-crystalline granules and the shape criteria of granules are oval and rounded that can be looked at microscopic techniques. The granule surface was investigated by atomic force microscopy (AFM) in the non-contact mode to give the results of the structural details [13]. Besides that from the previous study, combination of cassava starch with a cationic polymer, such as polydiallyldimethylam-ammonium chloride makes flocculation capacity more effective [11].

This research was proposed an environmentally friendly method that was used cassava peel starch as the alternative coagulant based on its low-cost, renewable waste and easy to find and get as a coagulant for the removal of water turbidity [14]. In the present study, coagulation-flocculation test was conducted using natural coagulant cassava peel starch to improve its properties by comparing with aluminum sulfate (alum) in the water treatment.

II. FRAMEWORK STUDY

The flowchart of methodology for this study.

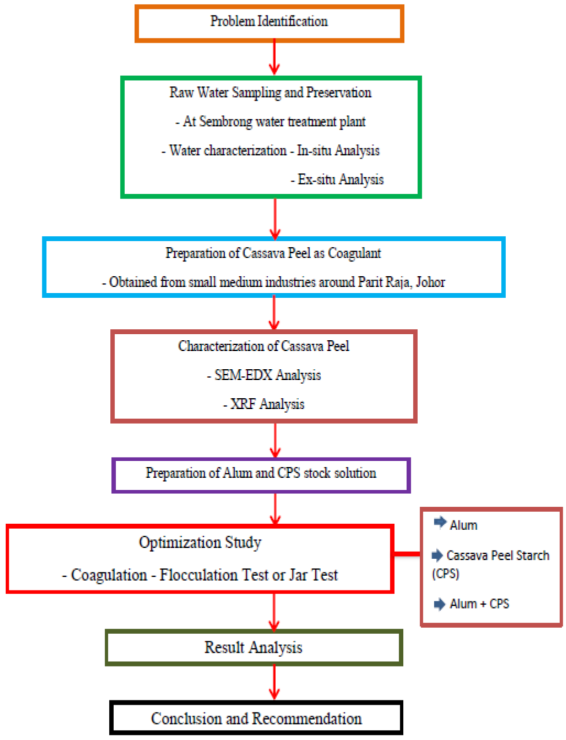

Fig. 1. Research Framework

Figure 1 illustrates the process of methodology that covers research from the beginning until the end of this study.

III. MATERIALS AND METHODS

A. Raw Water

Raw water samples were collected once a week from raw water inlet at Sembrong water treatment plant, Sembrong, Johor, Malaysia. The water was collected in 500 mL HDPE bottle [15]. All sampling bottles were rinsed with distilled water to remove any contaminants at the apparatus. Samples bottles were fully filled with water samples to guarantee no air bubbles trapped and natural particulate matter captured in the bottles. The appearance of trapped air bubble may disturb the next process. The sample were put away in a cooler and transported back to the lab for analysis on the same day [16]. At that point water samples were put away at 4°C preceding further analysis [16]. The sample of Sembrong dam water was analyzed at the laboratory of Environmental Engineering, Universiti Tun Hussein Onn Malaysia. Before start the coagulation and flocculation process, the water parameter was determined first to make sure the cassava peel can give significant effect in removing the pollutant. Then, the water samples was filtered through 0.45 µm filter paper using glass filtration unit. The parameters that was tested are temperature (°C), TSS (mg/L), turbidity(NTU), pH, COD (mg/L) and DO (mg/L).

B. Preparation of Cassava Peel Starch (CPS) as Coagulant Aid

The cassava peel (CP) was obtained from local industries around Parit Raja, Johor, Malaysia.

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The preparation was according to [17,18]. Qualified peels were selected and cleaned carefully using tap water before rinse with distilled water and allowed for sun-dry for 48 hours. Subsequently, the peel was oven dried in 60°C until it reaches constant weight. The dried peel was ground into fine powder using domestic blender and subsequently was sieved to sizes between 400 - 800 µm. The powder then was restored in an air tight container for further use.

C. SEM-EDX

A scanning electron microscope (SEM) functions to the analyse of surface morphology in cassava peel. The benefit of SEM-EDX is the percentage of an element that contains the granular particles and only can shoot the surface of the cassava based on the granular particles that were chosen. The SEM-EDX analysis was used to obtain high resolution image of coagulant prior and after coagulation studies at Materials Characterization Laboratory, UTHM.

D. XRF

The main function of XRF (X-Ray Fluorescence analysis) is to determine the elemental composition of the cassava peel. The benefit of XRF, the whole sample can be look compared to SEM-EDX analysis. The cassava peel was prepared in powder form then changes into the form of the palette to place in the XRF machine.

E. Preparation of CPS Stock Solution

Stock solution of 1000mg/L for CPS was prepared by adding 1g of CPS powder into 1L of distilled water [17,18]. The suspension was stirred for 1 hour in order to make sure the powder mix uniformly [17,18]. The calculation for dilution of stock solution was done using the following equation:

$$M_1V_1 = M_2V_2 \qquad (1)$$

Where:

M_1= Initial concentration of stock solution (mg/l)

V_1= Volume of stock solution desired (L)

M_2= Amount to produced concentration of solution (mg/l)

V_2= Amount to produced volume of solution (L)

F. Preparation of Alum Stock Solution

Alum solution was prepared by dissolving 10 g Aluminium Sulphate ($Al(SO_4)_3.18H_2O$) in 1L of distilled water [17,18]. This stock solution was used to prepare alum solution of varying concentration of the water samples.

G. Coagulation and Flocculation Test

This process coagulation and flocculation were used by a method of jar test experiment. Jar test apparatus consists of a motor was equipped with six rowers, equipped with six beaker filled of 1 liter volume of Sembrong dam water. It was carried out as a batch test, accommodating a series of six beakers together with six-spindle steel paddles.

Jar test were done by using a coagulant cassava peel starch + aluminium sulfate, aluminium sulfate only and cassava peel starch only. This test was repeated three times to obtain the optimum value and average value. Working conditions on mixing phase were kept constant of rapid mixing with 200 rpm run for 1 minutes, 100 rpm run for 2 minutes and slow mixing with 25 rpm run for 30 minutes.

After completion every set of jar test, the water sample and the floc on the bottom of the beaker were collected for further analysis. The turbidity parameter was measure by using Hach turbidity meter. Calculation for percentage removal was calculated using the equation below:

$$\text{Removal}(\%) = \left(\frac{(C_i - C_f)}{C_i}\right) \times 100 \qquad (2)$$

Where:
C_i=Initial turbidity of the sample;
C_f =Final turbidity of the sample

Table- I: Jar test working condition

Coagulant	pH	Coagulant dosage (mg/l)	Settling time (min)
Alum	2, 3, 4, 5, 6, **7**, 8, 9, 10, 11	5, 10, **15**, 20, 25, 30	10, 20, 30, **60**, 90, 120
CPS	3, 3, 4, 5, 6, **7**, 8, 9, 10, 11	100, **200**, 300, 400, 500, 600	10, 20, 30, **60**, 90, 121
Alum + CPS	4, 3, 4, 5, 6, 7, 8, **9**, 10, 11	100%:0%, **70%:30%,** 50%:50%, 30%:70%, 0%:100%	10, 20, 30, **60**, 90, 122

Note: **9** (bolt number) is optimum value that kept constant
References: pH- [19,20]
Coagulant dosage- [20,21]
Settling time- [21,22,23]

H. Water Analysis

Water test procedures that were used throughout this study to analyze the water from Sembrong Dam water before and after treatment. Each test was read on three different samples to obtain the average value. The analysis was conducted on pH, dosage and settling time to remove turbidity, TSS and COD in water.

IV. RESULT AND DISCUSSION

A. SEM-EDX Analysis Before Jar Test

The surface morphologies of the cassava peel starch samples are depicted in Figure 2 and Figure 3 show EDX spectrum for native CPS. Based on the SEM micrographs, it was observed that the cassava peels surface shows non-porous and heterogeneous characteristics [24]. Smooth and globular in shape of bound starch granules were observed to mostly cover general surface of cassava peel starch and appeared to be in cluster on cassava peel starch it might due to cassava peel waste composed of the flesh layer.

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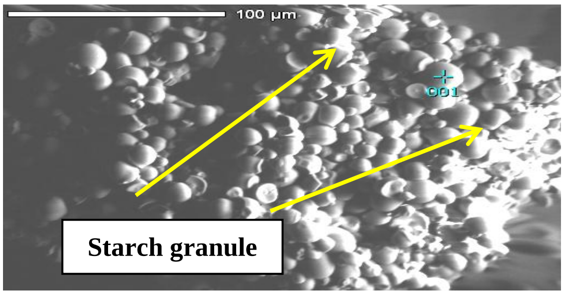

Fig. 2. SEM micrograph of native cassava peel.

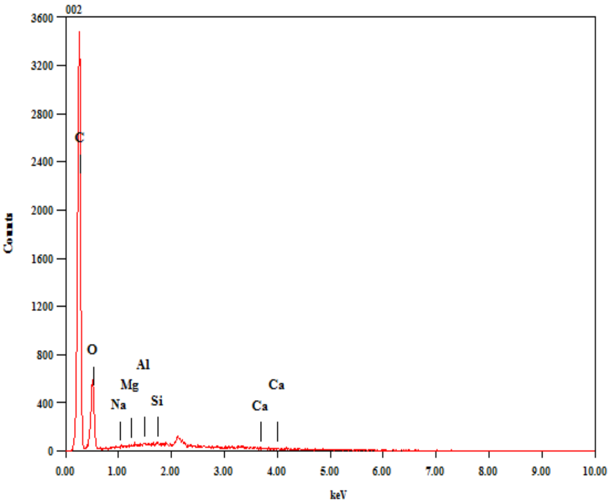

Fig. 3. EDX spectrum of native cassava peel.

B. SEM-EDX Analysis After Jar Test

The experiments analyses were carried out on alum, CPS and alum + CPS by flocculation analysis. Figure 4 and Figure 5 show the alum floc in the formation of shaped pieces with veined and no regular.

The SEM-EDX of coagulated floc after the coagulation treatment using cassava peel starch (CPS) floc are presented in Figure 6 and Figure 7. The formed in a granular shape was found in the surface morphology of CPS floc. It is found that the floc analysis was formed in a granular shape. Its demonstrated that smooth and globular in shape of bound starch granules were observed [25].

Figure 8 and Figure 9 show the SEM-EDX of alum + CPS floc. The SEM image presents in the form of pieces. The alum + native cassava peel has proven to improve the morphology of the coagulant surface that increasing the possibility of retaining metallic ions in different parts of the coagulant [26].

Therefore, shiny particles observed over the surface of floc after the jar test study was conducted [27]. From the observation after the analysis of jar test evidenced the surface coverage of coagulation and flocculation by metal ions [27]. The flocculation that were presented from the SEM and EDX images analysis, it shows that the natural coagulants of cassava peel starch utilized in the research have comparable attributes with the industrial waste coagulants like alum on evacuating turbidity, TSS and COD content from the water treatment plant samples.

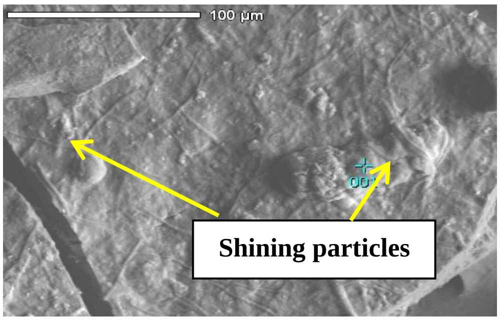

Fig. 4. SEM micrograph of alum floc.

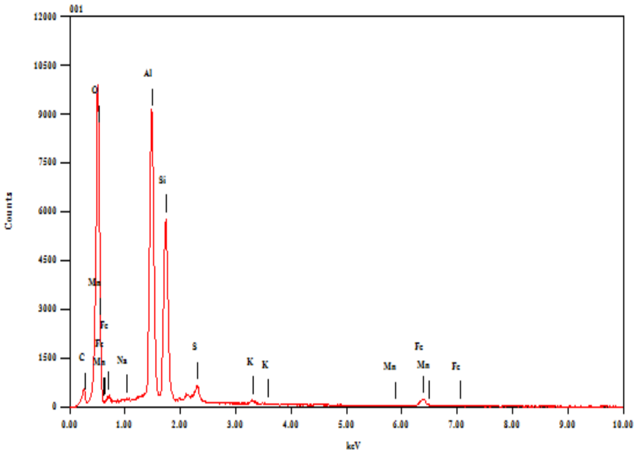

Fig. 5. EDX spectrum of alum floc.

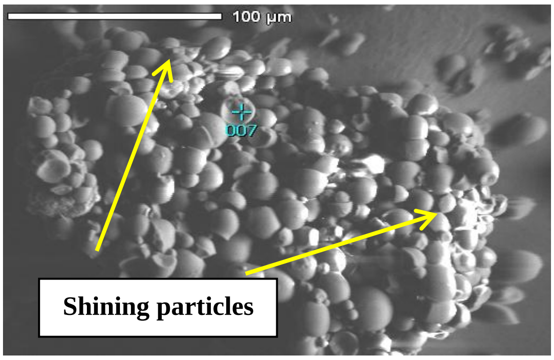

Fig. 6. SEM micrograph of CPS floc.

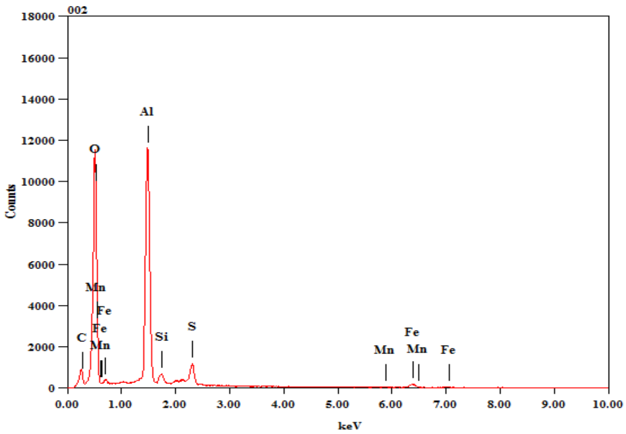

Fig. 7. EDX spectrum of CPS floc.

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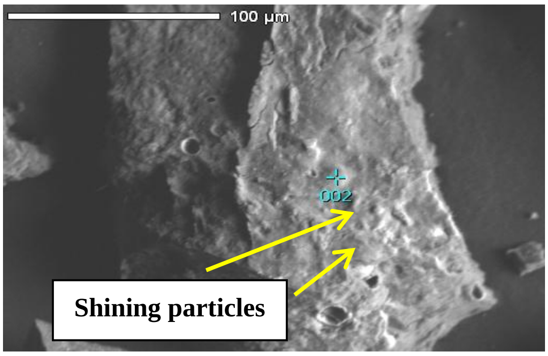

Fig. 8. SEM micrograph of alum + CPS floc.

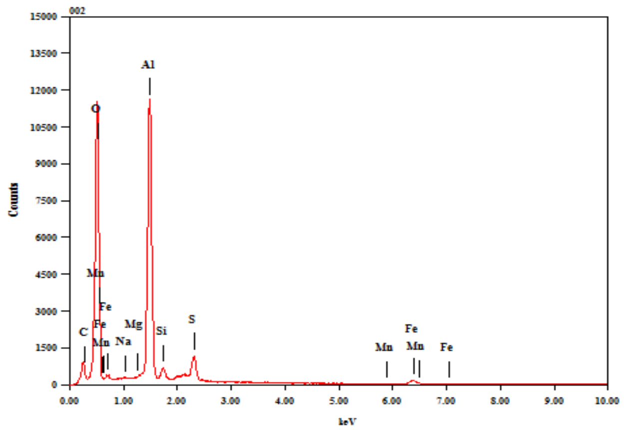

Fig. 9. EDX spectrum of alum + CPS floc.

C. XRF Analysis

The elemental analysis of cassava peel was done using XRF. Table-II shows the results elemental composition of cassava peel. The cassava peel was present by the element that gave it the coagulant properties are Al_2O_3 and Fe_2O_3. Both elements were expected to give the cassava peel the ability to aid the coagulation process by using precipitation of the particles in the raw water. The presence of SiO_2 and CaO in cassava peel might help in the increase of weight and size to particles in the raw water as a flocculation aid become faster [27, 28].

Table- II: Elemental composition of cassava peel

Formula	Weight (%)
	CPS
C	0.10
O	5.83
CaO	**3.48**
Fe_2O_3	**0.41**
SiO_2	**0.40**
SO_3	0.94
Al_2O_3	**0.26**
P_2O_5	0.42

D. Effect of Dosage

Figure 10 demonstrates the level of removal turbidity expanded up to 86.04% with expanding of alum dose from 5 – 25 mg/L. The removal percentage level of COD was expanded from 23.08% to 52.31% with the high of alum dosage from 5 – 25 mg/L. Besides that, the recommended dosages to achieve the highest removal of TSS using alum alone is (83.33%) were 5 and 30 mg/L respectively. Furthermore, based on the previous study of potential use of rice starch in coagulation–flocculation process of agro-industrial wastewater, the result also consistent with the literature which is the recommended dosages to accomplish the highest removal of TSS utilizing alum (86.3%) with concentration 0.3 and 2 g/L [29]. This can conclude that increasing alum dosage will result in progressively larger volumes of sediments and also enhance in TSS removal. Alum is normally high in control density when it is broken up in the suspension [30]. The present outcomes demonstrated that the coagulation component utilizing alum was for the most part in view of charge balance [31].

Figure 11 shows the percentage of turbidity removal was decreasing from 39.61% till the lowest which is 23.64% with additional CPS dosage from 100 - 600 mg/L. The percentage removal of COD decreases from 100 – 600 mg/L with the percentage removal from 28.26% to the lowest percentage of removal 12.32%. The study of the effect of cassava peel dosage on TSS removal reading found that the recommended dosages to achieve the removal TSS using cassava peel alone is 33.33% were respectively at 100 mg/L. It can be proven that using the cassava peel alone is less enhance rather than alum. But if the natural coagulant is added more dosage combined with the alum dosage, it will make the bridge of flocculation more effective and easy to settle down. Furthermore, based on the previous study, they have been expressed that the substance of organic matter was raised when natural coagulants were utilized and furthermore because of its biological nature [32].

Figure 12 shows the effect of alum + CPS dosage. Based on the graph and the results, the turbidity and TSS percentage increase which is (82.82% to 90.32%) and (79.37% to 90.48%) at ratio 100: 0 to 70: 30. Moreover, after adding the cassava peel dosage the percentage becomes higher than before. This can conclude that the combination of aluminum sulphate + cassava peel dosage enhanced the water treatment in coagulation and flocculation process. The cassava cannot formed floc by itself and only can used as coagulant aid. Meanwhile the percentage of COD is decrease slightly. The data shown that from 100 : 0 to 0 : 100 was 21.38% to 8.18%. Aluminium sulphate + cassava peel dosage was used to help the process of coagulation and flocculation test with treatment of water. From the experiment, it shows that alum : cassava peel which 70 : 30 was the best removal of turbidity, TSS and COD. This proven that can decreases the usage of alum to get the objectives.

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Working condition used for optimization effect of dosage by alum, CPS dosage with constant (pH=7, settling time = 60 min, mixing = 200 rpm -1 min, 100 rpm-2 min and 25 rpm-30 min). While, by alum + CPS with constant condition (pH =9, settling time = 60 min, mixing = 200 rpm -1 min, 100 rpm-2 min and 25 rpm-30 min).

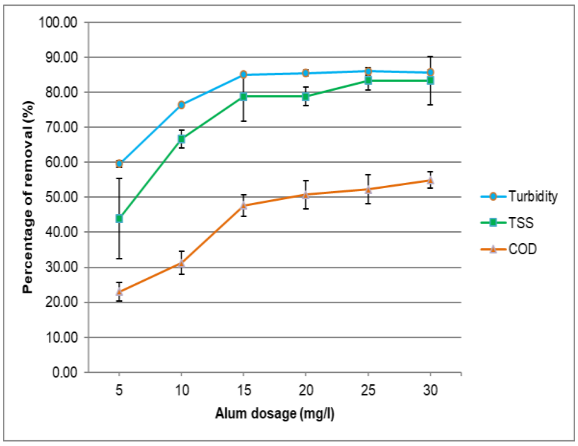

Fig. 10. Effect of Alum Dosage.

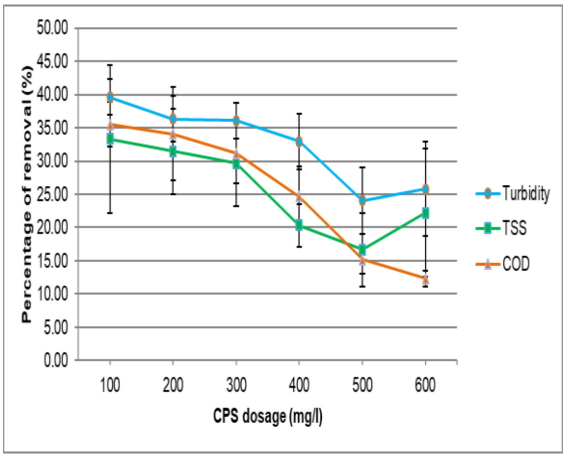

Fig. 11. Effect of CPS Dosage.

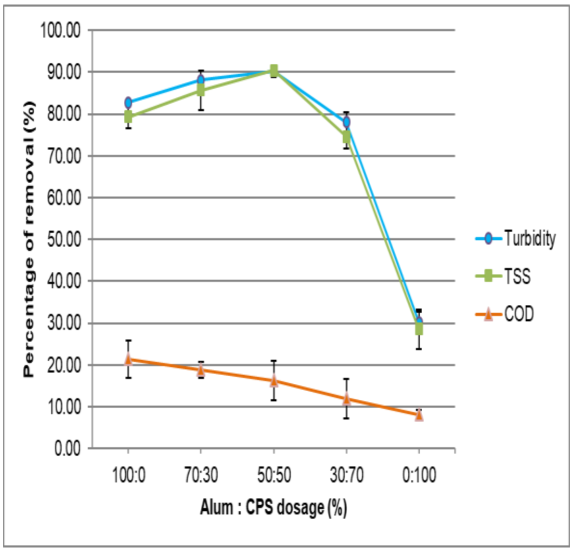

Fig. 12. Effect of Alum + CPS Dosage.

E. Effect of pH

In order to establish on pH that effects coagulation and flocculation process onto alum, cassava peel sample and cassava peel + alum toward turbidity removal, batch process studies were conducted at different initial pH values in range of 2 – 11 for all batch process of jar test. Figure 13 shows the effect of pH on turbidity removal. The maximum turbidity removal was observed at pH 7 for alum, pH 11 for CPS and pH 9 for alum + CPS. The turbidity removal for CPS was increased because CPS are on alkali and CPS can not use to be main coagulant without any usage of chemical. Then, CPS need high pH to remove higher turbidity. Interestingly as the pH higher, all the more negatively charged surface wind up noticeably accessible, subsequently encouraging more noteworthy metal adsorption [33].

Based on the results in Figure 14, cassava peel sample (CPS) exhibited higher coagulation activity with maximum COD removals of 25.36 % under acidic conditions from pH 2 to 5. Therefore, the charge of Cassava peel in the solution did not play a critical role for this mechanism. On the other hand, alum and alum + cassava peel performed better conditions with maximum COD removals of 46.67 and 32.70% respectively. Alum and alum + cassava peel resulted in lower COD removals ranged pH from 5 - 7. Therefore, increases in COD removals from raw water using all the test were observed above pH 11.

The effect of pH on TSS removal is shown in Figure 15. Based on the graph and results, TSS removals were investigated between pH 2-11 and what was observed, that the highest TSS removal at pH 7 for alum (80.30%), pH 2 for cassava peel (77.78%) and pH 9 for a combination of alum and cassava peel (92.06%) respectively. For the TSS removal of alum, the results are continues increased between pH 2-7, while for the TSS removal of cassava peel, the results are decreased drastically between pH 2- 10. Besides that, the TSS removal of a combination of aluminum sulphate and cassava peel, the results were increased drastically between pH 3- 9. For the observation based on the results that had been stated, the highest of TSS removal for cassava peel is pH 2.This can be proven that the result is consistent with the literature which had been stated that lower pH was good for flocculation process using natural coagulant and also increasing pH would leading to decreased TSS removal [26]. This can be proven based on the results, the combination of aluminum sulphate and cassava peel, the percentage removal of TSS is continues decreased at pH values in the range of 9-11.

Working condition used for optimization effect of pH by alum (alum dosage = 15 mg/l), by CPS (CPS dosage = 200 mg/l) and alum + CPS (10.5 mg/l : 60 mg/l), (settling time = 60 min, mixing = 200 rpm -1 min, 100 rpm-2 min and 25 rpm-30 min).

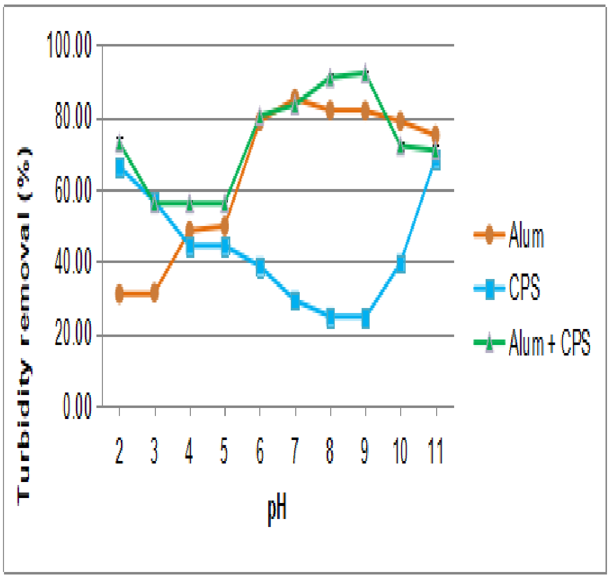

Fig. 13. Effect of pH on turbidity removal.

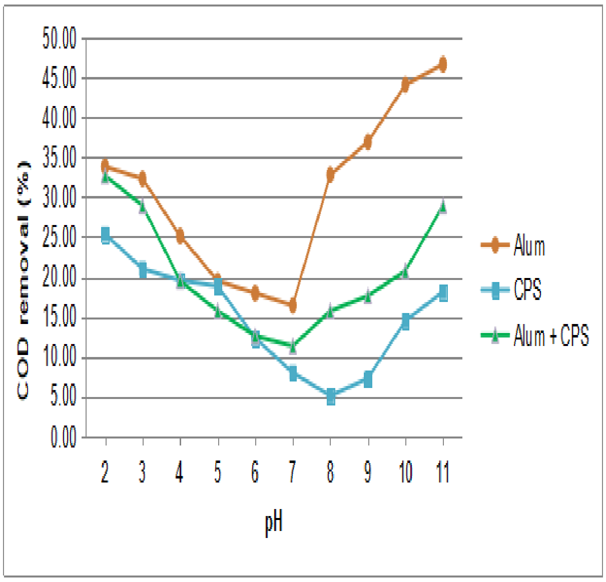

Fig. 14. Effect of pH on COD removal.

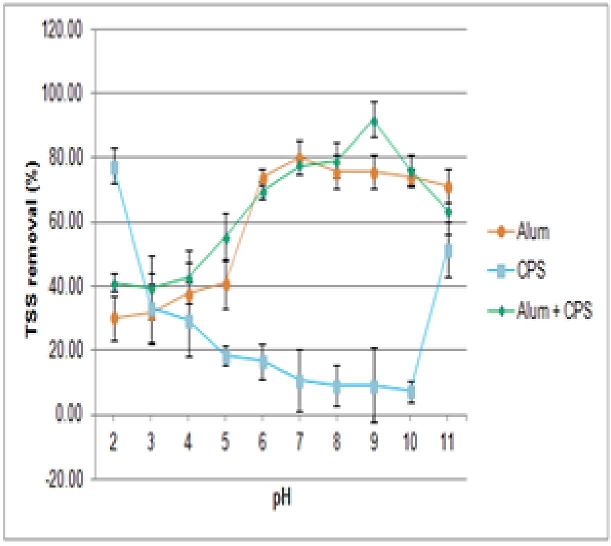

Fig. 15. Effect of pH on TSS removal.

F. Effect of Settling Time

Figure 16 demonstrates that coagulation process without presenting settling yielded lower removal of turbidity 69.02, 26.41 and 85.90% for alum, CPS and alum + CPS. Then again, the remittance of settling time from 10 to 30 min brought about progress of turbidity increment for alum, CPS and alum + CPS, respectively. Removal efficiency of turbidity after 30 min show a good result. The more time to take for a settling time of the process, more turbidity can remove from the raw water [33].

Figure 17 demonstrates the impact of settling time on removal of COD. From the outcome, removal COD was expanded begun from 20 min for all batch process. Alum, CPS and Alum + CPS was highest on COD removal for 120 min with the removal 19.87, 11.54 and 17.95%. Among the three type of coagulant test, alum show a good result because used 100% of main coagulant. The settling time for CPS was a lowest data and it show that Cassava peel can not help flocculation test by itself [26].

The effect of settling time on TSS removal is shown in Figure 18. The study of the effect of settling time on turbidity removal was conducted at the initial turbidity which is 23 for all the coagulants. Based on the graph and results, TSS removals were investigated between settling time in range 10 – 120 minutes. The highest TSS removal was observed at settling time 120 minutes for alum (86.96%), for cassava peel (28.99%) and for combination of alum and cassava peel (89.86%) respectively. For the TSS removal of alum and cassava peel, the results are continues raised while the combination of aluminum sulphate and cassava peel the results is slightly fluctuated between settling time in the range 60-120 minutes. Based on the results, the more raised settling time, the more highest the TSS removal and the good results for settling time is 120 minutes compared to 10 minutes. Besides that, the settling time for cassava peel alone is not high for TSS removal compared to aluminum sulphate (alum) which can give the good flocculation process by itself [34]. The combination of aluminum sulphate and cassava peel, it showed that the cassava peel can be as coagulant aid and can reduce the chemical coagulant represent at cassava peel incase molecule weight for floc settle [26].

Working condition used for optimization effect of settling time by alum (alum dosage = 15 mg/l), by CPS (CPS dosage = 200 mg/l) and alum + CPS (10.5 mg/l : 60 mg/l), (pH = 7, mixing = 200 rpm -1 min, 100 rpm-2 min and 25 rpm-30 min).

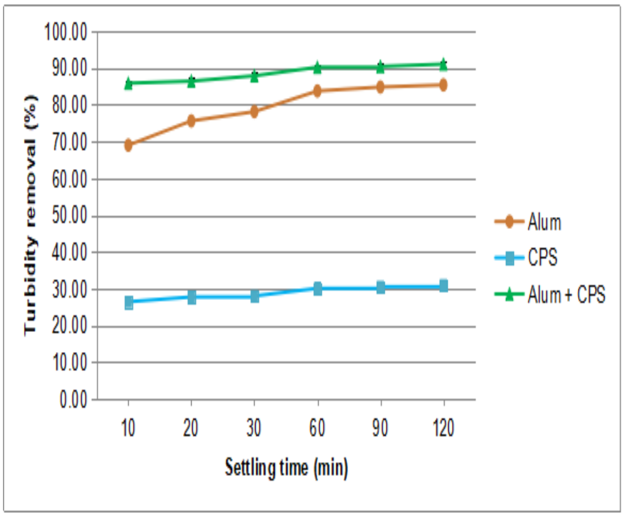

Fig. 16. Effect of Settling Time on Turbidity Removal.

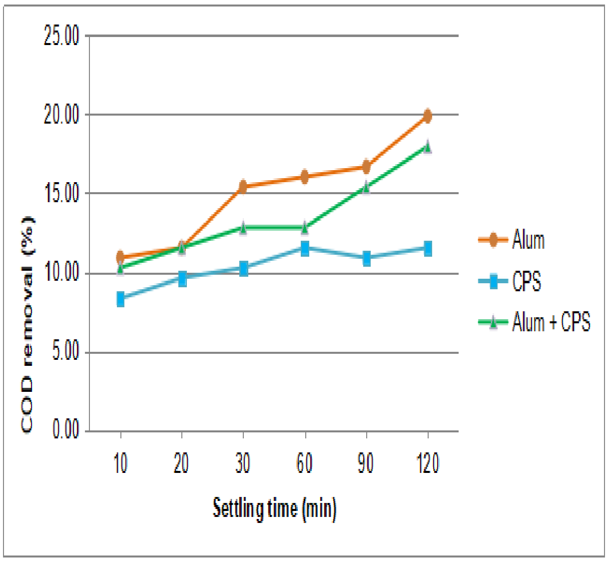

Fig. 17. Effect of Settling Time on COD removal.

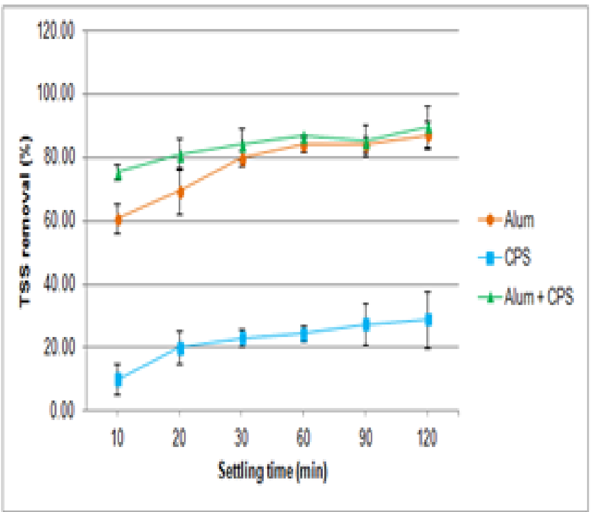

Fig. 18. Effect of settling time on TSS removal.

IV. CONCLUSION

The present study pursued a new alternative coagulant, namely cassava peel that is biodegradable and natural to the environment and living organisms. The use cassava peel showed the positive results to reduce the dosage of chemical coagulant in water treatment. The cassava peel was actually more weight from the aluminium. It is because the cassava peel has more starch of the peel. The alum dosage was observed to be optimum at 15mg/L with turbidity removal of 85.02%, TSS removal of 83.33% and COD removal of 47.69%. The pH value was optimum at pH 7 with 84.99% of turbidity removal and 80.30% for alum meanwhile the pH value was optimum at pH 11 with 46.67% of COD removal. The CPS dosage was observed to be optimum at 200mg/L with turbidity removal of 39.61% and COD removal of 28.26% while highest removal of TSS using CPS is 39.61%. The pH value was optimum at pH 11 with 70.69% of turbidity removal and the pH value was optimum at pH 2 with 25.36% and 77.78% of COD removal and TSS removal. The alum : CPS dosage was observed to be optimum at 70:30% with turbidity removal and TSS removal of 90.32% meanwhile COD removal of 18.87%. The pH value was optimum at pH 9 with 92.11% of turbidity removal and pH value was optimum at pH 2 with the percentage COD removal is 32.70%. Therefore for combination alum and cassava peel at pH 9 with 92.06%. The settling time within 10 minutes, the turbidity removal and TSS removal has reached up to 80% meanwhile the COD removal have reached up to 15% for alum, CPS and alum + CPS. Besides that, the best removal is in the ratio 70: 30 percentage used by alum + cassava peel sample. The treatment use by combination alum + CPS show highest removal especially in turbidity removal compared with treatment use by alum alone. Thus compare treatment successful reducing alum usage and overall experimental result can concluded that the Cassava peel starch has the potential to be used as an economically and eco-friendly coagulant aid for the removal of turbidity, TSS and COD from raw water.

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