Degradation of chemical oxygen demand, suspended solids and ammoniacal nitrogen from sewage by sweet potato peel coagulant under the influence of pH

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Abstract. Coagulation is a common treatment stage included in conventional sewage treatment. Various chemical, synthetic and natural coagulants in the form of single, dual and composite were applied in this treatment stage. However, the application of natural coagulants made from food waste is still uncommon. Thus, this study compares the ability of sweet potato peel as a composite coagulant (PACSPP), dual coagulant (PAC+SPP) and single coagulant (SPP) under the influence of pH in removing chemical oxygen demand (COD), suspended solids (SS) and ammoniacal nitrogen (AN) from sewage wastewater. Raw sewage sample before primary treatment was collected from University Tun Hussein Onn Sewage Treatment plant by using grab sampling method. Optimization study was conducted by using jar tester. Atthe optimum condition of PACSPP (pH 7), the percentage removal of COD, SS and AN was 54%, 95% and 39%. While a single SPP coagulant, at its optimal pH of 9, achieved 24%, 16% and 17% removals of COD, SS and AN, respectively. Meanwhile, optimisation of dual coagulant (pH 9) demonstrated 39%, 73% and 42% removals of COD, SS and AN, respectively. Thus, SPP, as a composite coagulant, outperformed the dual and single coagulant of SPP.

1. Introduction

Coagulation has conventionally been used in various water and wastewater treatment for clarification purposes. Moreover, coagulation is the most commonly employed treatment technology for economic reasons. The factors that determine the effectiveness of coagulation is the optimum condition of its operating factor (ex: mixing intensity, mixing duration, type of coagulant, dosage, pH, and settling time). Thus, the determination of the best condition of operating parameters is vital in this treatment method.

Monomeric coagulants (aluminium chloride, aluminium sulphate, ferric chloride, ferric sulphate) and polymeric coagulant (polyaluminium chloride (PAC), polyferric chloride (PFC)) are typically used in coagulation. However, this chemical coagulant has health effects and drawbacks, such as Alzheimer's disease. [1]. Thus, an alternative coagulant, such as a natural coagulant, has obtained attention. Furthermore, a natural coagulant is affordable, safe and biodegradable. Plants, animals and microbes are the three main sources of natural coagulants [2]. In the present study, starch derived fromsweet potato peel (SPP) was proposed as a coagulant for sewage treatment. SPP is agriculture waste that has the potential to be used as a coagulant by utilising the starch content in the peel.

Starch contains a polymer that has the ability to form heavy and strong floc that is able to enhance the coagulation process. In addition, starch coagulant is cheaper compared to other natural polymers such as chitosan [3]. In most of the reported previous studies, the starch used was from the starch powder obtained from the flesh of the root [4][5][6]. However, for this study, the peel of the root was used. The application of SPP is not widely studied in sewage treatment. Therefore, this study aims to determine the ability of SPP as a coagulant in the different coagulant forms (single, dual and composite) under the influence of pH in degrading COD, SS and AN from sewage wastewater.

2. Materials and Methods

2.1. Sewage Sampling

Raw sewage sample before the primary treatment stage was collected from the Universiti Tun Hussein Onn Malaysia (UTHM) sewage treatment plant. The treatment plant serves a population of 15,344 within the campus. Grab sewage sample was taken immediately and transported to Micro Pollutant Research Centre (MPRC) laboratory and stored in a chiller at a temperature of 4°C before analysis. The sampling and storage of sewage samples were performed according to the Standard Methods for Examination of Water and Wastewater [7]. The sample collected was used for the characterisation and optimisation of the coagulant. Table 1 shows the characterisation of sewage used for this study.

Table 1. Characteristics of UTHM Sewage

Parameter	Year 2023			Average Value
	March	April	May	
Ammoniacal Nitrogen (mg/L)	1.56	1.61	4.68	2.62
Chemical Oxygen Demand (mg/L)	50	87	40	59
Suspended Solids (mg/L)	28	48	45	40.33
pH	8.09	6.01	5.56	6.55
Temperature (Celcius)	25.3	24.1	24	24.47

No. of samples for three months: 11

2.2. Equipment and Reagent

Table 2 shows the equipment, reagent and method used in the analysis of parameter suspended solids, SS, pH, AN, and COD.

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2.3. Coagulation Process

The sample was stirred for 4 minutes at 200 rpm during the rapid mix stages. Then, during slow mixing, the speed was reduced to 30 rpm for 15 minutes. Finally, the sample was allowed to settle for 30 minutes, and the supernatant was then collected using the syringe below 3 cm from the surface for COD, SS and AN analysis. The removal percentage of COD, SS and AN were calculated based on Equation 1.

$$Removal\ (\%) = \frac{C_0 - C_f}{C_0} \times 100 \quad (1)$$

Where, C_0 is the initial concentration of each removal parameter, while C_f is the final concentration of each parameter.

Table 2. Equipment and reagent used in this experiment

Parameter	Equipment	Reagent	Standard Method
Suspended solids	DR6000		APHA 2540D
pH	pH meter	Distilled water	APHA 4500-HB
Ammoniacal-nitrogen	DR6000, pipet, and graduated cylinder	Reagent Nessler, Polyvinyl alcohol, mineral stabiliser, and deionised water	HACH 8038
Chemical Oxygen Demand (COD)	DRB 200 reactor beaker and pipet.	Sulphuric Acid (H_2SO_4), Potassium Dichromate ($K_2Cr_2O_7$), Mercuric Sulphate ($HgSO_4$), and COD digestion vial (high range).	HACH 8000
Coagulation	Jar tests VELP-Scientific, ModelJLT6 (Italy)	0.1M (H_2SO_4),1N sodium hydroxide (NaOH), 40 ml sodium chloride (NaCl)	ASTM D2035

2.3.1 Preparation of composite coagulant (PACSPP)

A peristaltic pump was used to inject a heated SPP solution into a 100 mL solution of PAC. The amount of SPP was calculated in volume (mL) using Equation 2. 4 g of PAC and 6 g of SPP were stirred magnetically (300-400 rpm) to avoid the production of insoluble compounds during the injection. The peristaltic pump flow rates were set at 2 mL/min, the water bath temperature was set at 180 °C, and the solution was maintained at 65–75 °C [8][9].

$$M_1V_1 = M_2V_2 \quad (2)$$

Where:
M_1 = 10% of concentration of stocks solution of coagulant
V_1 = Volume of initial solution (mL)
M_2 = Dosage of coagulant
V_2 = Volume of wastewater sample

2.3.2 Preparation of Single Coagulant (SPP)

3 g of SPP was weighed and diluted in 100 mL of distilled water and gelatinise. Dosage was calculated based on Equation 2.

2.3.3 Preparation of dual coagulant (PAC+SPP)

10 g of PAC was diluted into 100 mL of distilled water. 3 g of SPP was weighed and diluted in 100 mL of distilled water and gelatinise. PAC was added at the beginning of rapid mixing. Meanwhile, SPP was added before the slow mixing started. The dosage for PAC and SPP was calculated based on Equation 1.

3. Results and Discussion

The comparison of optimisation of SPP at different pH is shown in Figures 1-3. According to Figure 1, pH 7 demonstrated the best COD removals for PACSPP (42%) and PAC+SPP (40%). In contrast, for SPP, the best removal is at pH 9 (25%). In terms of COD removal, SPP in the form of composite and dual had almost similar degradation ability. However, PACSPP shows the best COD degradation ability compared to PAC+SPP and SPP. As shown in Figure 2, PAC+SPP removed AN bettercompared to PACSPP and SPP. The highest AN removal of PAC+SPP is at pH 9, with 58%.Meanwhile, PACSPP and SPP optimum AN removal are at pH 7 (20%) and pH 9 (12%), respectively. According to the data analysis, the type of coagulant form does affect the performance of the coagulant. PAC+SPP capability for AN removal outperformed PACSPP and SPP. Figure 3 demonstrates the effect of pH on SS degradation. In general, PACSPP recorded way better SS removalcompared to PAC+SPP and SPP for all the pH ranges tested. The highest SS removal was recorded at pH 7 with 90%. Meanwhile, PAC+SPP and SPP obtained 42% and 16% at optimum pH.

Overall, as can be seen from data analysis, SPP as the single, dual as well composite form is able to degrade COD, AN and SS from sewage wastewater. However, each coagulant form achieved its peak degradability capability at a certain pH value. As for PACSPP, the optimum pH is 7. Meanwhile, pH 9 is the optimum pH condition for PAC+SPP and SPP. Further increment of pH beyond optimum pH does not appear to be beneficial for the degradability rate, which indicates restabilization of colloidal particles due to charge reversal [1] . The degradability rank for COD is PACSPP>PAC+SPP>SPP, AN is PAC+SPP>PAC+SPP>SPP, and SS is PACSPP>PAC+SPP>SPP. Thus, composite coagulant (PACSPP) is the best coagulant form compared to dual coagulant (PAC+SPP) and single coagulant (SPP). SPP as a single coagulant obtained the lowest degradability rate, and this finding is in accordance with the previous study that used starch as a coagulant [1][4][5]. However, the integration of SPP with PAC as a dual and composite coagulant increases its removal ability. SPP acted as coagulant aid. As SPP combined with PAC as composite or dual coagulant, the performance of coagulation is determined by the pH tolerance of the main coagulant used [8]. Thus, as SPP combined with PAC, the removal ability improved compared to the single SPP. Therefore, it can be concluded that the type of coagulant form and pH affect the degradability capability of the coagulant.

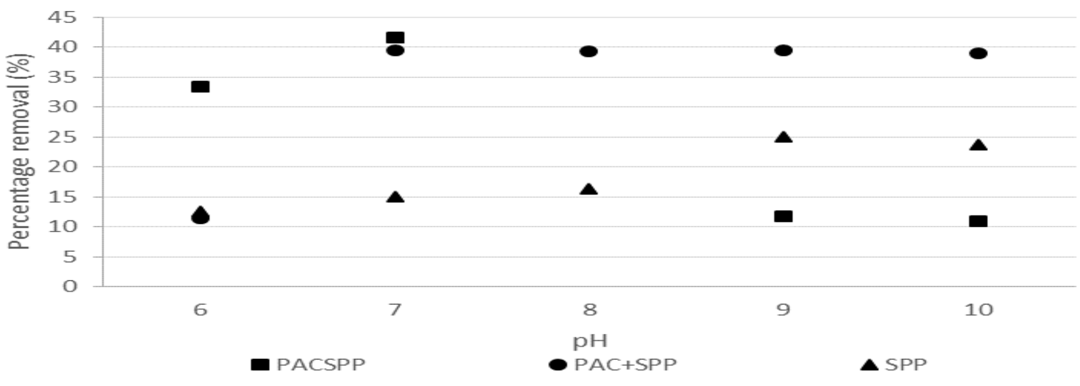

Figure 1. Effect of pH on COD removal (PACSPP dosage = 4000 mg/L; PAC+SPP dosage = 300 mg/L +200 mg/L; SPP dosage = 100 mg/L; rapid-mixing = 200 rpm-4 min; slow-mixing = 30 rpm-15 min; settling time 30 min)

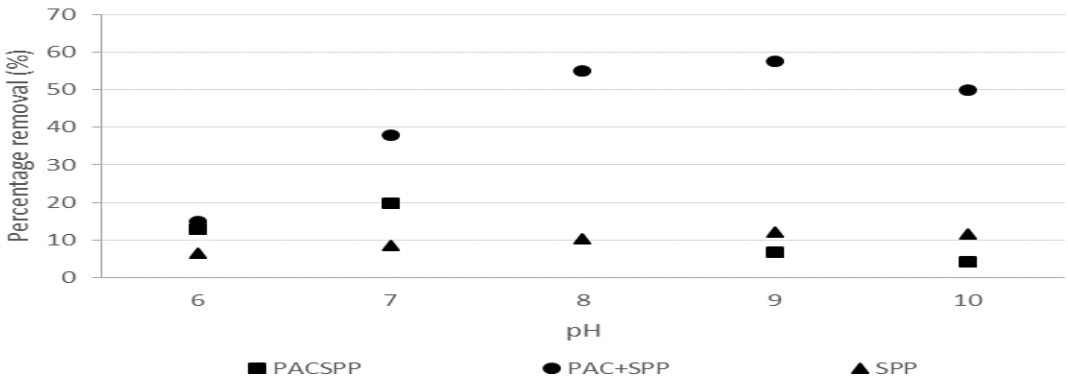

Figure 2. Effect of pH on AN removal (PACSPP dosage = 4000 mg/L; PAC+SPP dosage = 300 mg/L +200 mg/L; SPP dosage = 100 mg/L; rapid-mixing = 200 rpm-4 min; slow-mixing = 30 rpm-15 min; settling time 30 min)

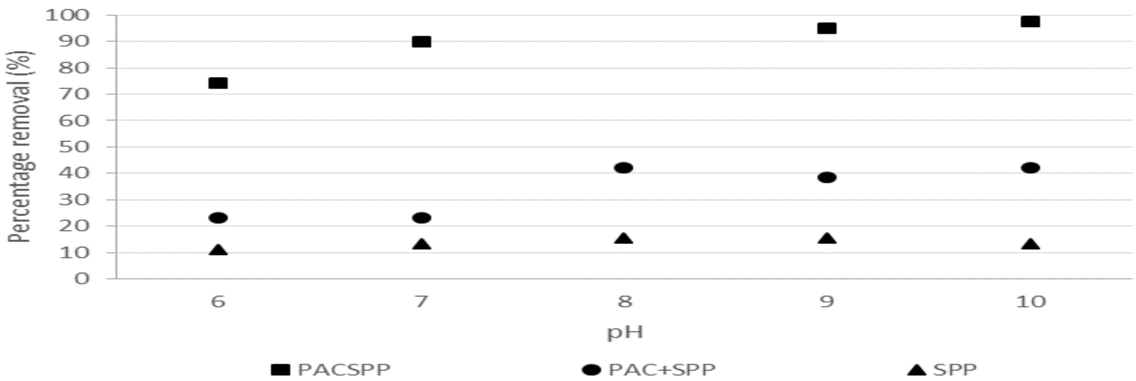

Figure 3. Effect of pH on SS removal (PACSPP dosage = 4000 mg/L; PAC+SPP dosage = 300 mg/L +200 mg/L; SPP dosage = 100 mg/L; rapid-mixing = 200 rpm-4 min; slow-mixing = 30 rpm-15 min; settling time 30 min)

4. Conclusion

Sewage wastewater treatment was done by using a coagulation-flocculation process with SPP in the form of composite coagulant (PACSPP), dual coagulant (PAC+SPP) and single coagulant (SPP). The results indicated that PACSPP recorded the best degradation ability compared to PAC+SPP and SPP at optimum pH. The optimum pH condition for PACSPP is 7; meanwhile, PAC+SPP and SPP are pH 9. The degradability rank for COD is PACSPP (42%) > PAC+SPP (40%) > SPP (25%), AN is PAC+SPP (58%) > PAC+SPP (20%) > SPP (12%), and SS is PACSPP (90%) > PAC+SPP (42%) > SPP (16%). Hence, the integration of SPP with PAC as a dual and composite coagulant is able to increase the effectiveness of the SPP coagulation-flocculation process.

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