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ARTICLE

Domestic Wastewater Treatment through the Application of *Corchuros olitorius L.* as Bio-Coagulant in Cagayan de Oro City, Philippines

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ABSTRACT

This research paper presented the potential of *Corchuros olitorius L.* as a natural coagulant in the removal of turbidity, total suspended solids, and biochemical oxygen demand from the domestic wastewater of the University of Science and Technology of Southern Philippines. Optimization of the natural coagulant and synthetic coagulant was employed prior to the treatment design. The jar test method was used in the optimization and lab analysis including the gravimetric method, dilution technique, and digital measurements. The optimization results of *Corchuros olitorius L.* using the jar test method revealed better removal at a lower dosage of 50 mg/L and a higher settling time of 90 minutes. The characterization using FTIR analysis also suggests a functional group that influences coagulation activity. Using the optimum dose and optimum settling time, results with the different treatment designs showed the highest removal at pH 7 showed % BOD removal of 89.78% ($A_{75}C_{25}$); 85.98% ($A_{25}C_{75}$); 88.76% ($A_{50}C_{50}$). TSS removal measured values of 88.50% ($A_{75}C_{25}$), 85.56% ($A_{25}C_{75}$), and 87.16% ($A_{50}C_{50}$), while turbidity removal of 83.47% ($A_{75}C_{25}$), 80.27% ($A_{25}C_{75}$), and 80.27% ($A_{50}C_{50}$). Statistically, measured values differ between treatment designs. It is suggested to investigate removal efficiency in more varied pH conditions, different settling times, stirring speed, and other variables for future studies.

Keywords: *Corchorus olitorius L.*; Jar test; Optimization; Removal efficiency; Wastewater

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1. Introduction

Wastewater treatment is employed as an action to protect the quality of limited freshwater resources and therefore make it more acceptable for beneficial reuse [1]. Various traditional and advanced technologies have been utilized to remove colloidal particles from wastewater; such as ion exchange, membrane filtration, precipitation, flotation, solvent extraction, adsorption, coagulation, flocculation, and biological and electrolytic methods [2]. Among those methods, coagulation/flocculation is one of the most widely used solid-liquid separation processes for the removal of suspended and dissolved solids, colloids, and organic matter present in industrial wastewater [3]. Coagulation/flocculation is a commonly used process in water and wastewater treatment in which compounds such as aluminum sulfate, ferric chloride, and/or polymer are added to the wastewater to destabilize the colloidal materials and cause the small particles to agglomerate into larger settleable flocs [4].

Alum (aluminum sulfate), has been the most popular for the treatment of water and is widely used in treatment plants [5] but it has been found to pose some health, economic, and environmental problems upon usage, among which are neurological diseases such as percentile dementia and induction of Alzheimer's disease [6]. The use of synthetic flocculants like alum and iron can cause health hazards. Alzheimer's disease and dementia are associated with the use of aluminum ions in treated waters [7]. As a result, several studies have explored the use of natural coagulants as alternatives or an aid to chemical coagulants to eliminate or if not lessen their harmful effects. Bio-coagulants (plant materials) are considered a good substitute. Presently there is no study about *Corchuros olitorius L.* as a bio-coagulant in the treatment of domestic wastewater at the University of Science and Technology of Southern Philippines. Specifically, the study aims to: i.) Characterize *Corchuros olitorius L.*; ii.) Optimize pure *Corchuros olitorius L.* mucilage powder (C_{100}) using various coagulant dosages (50 mg/L, 100 mg/L, 150 mg/L), and settling time (30 min, 60 min, and 90 min) at pH 5, pH 7, and pH 9; iii.) Assess the removal efficiency of turbidity, total suspended solids (TSS), and biochemical oxygen demand (BOD) at different treatment designs.

2. Materials and methods

The methods used in this study are descriptive and experimental. One-way analysis of variance (ANOVA) using Microsoft Excel version 2016 at a 5% level of significance is used to determine the significant difference between the different treatments.

2.1 Research setting

Figure 1 shows the study area. The wastewater sample is collected at the sump pit of the University of Science and Technology of Southern Philippines, Cagayan de Oro Campus, and brought to the laboratory for coagulation treatment.

2.2 Collection of water sample

A wastewater sample is collected from the sump pit of the University of Science and Technology of Southern Philippines, Cagayan de Oro Campus. It is characterized as grey water, which is generated from the buildings of the school campus. The sample water is taken and brought to the school laboratory for its analysis using the coagulation process.

2.3 Preparation and characterization of *Corchuros olitorius L.* (Saluyot)

Powder preparation

Saluyot was harvested from the vacant lots of Barangay Iponan, Cagayan de Oro City, leaves were separated from the stalks, washed with distilled water, and boiled for 30 minutes. After boiling, the liquid is allowed to cool, and disintegrated and leaves were separated using a strainer followed by a cotton cloth to fully separate the slimy liquid. The extract that contains the viscous substance was separated from the leaf residue after filtration. Saluyot leaf extract was treated with 2-propanol in a 1:1 ratio to separate the viscous sediments known as the mucilage. It was then dried in an oven at 40 °C for 30

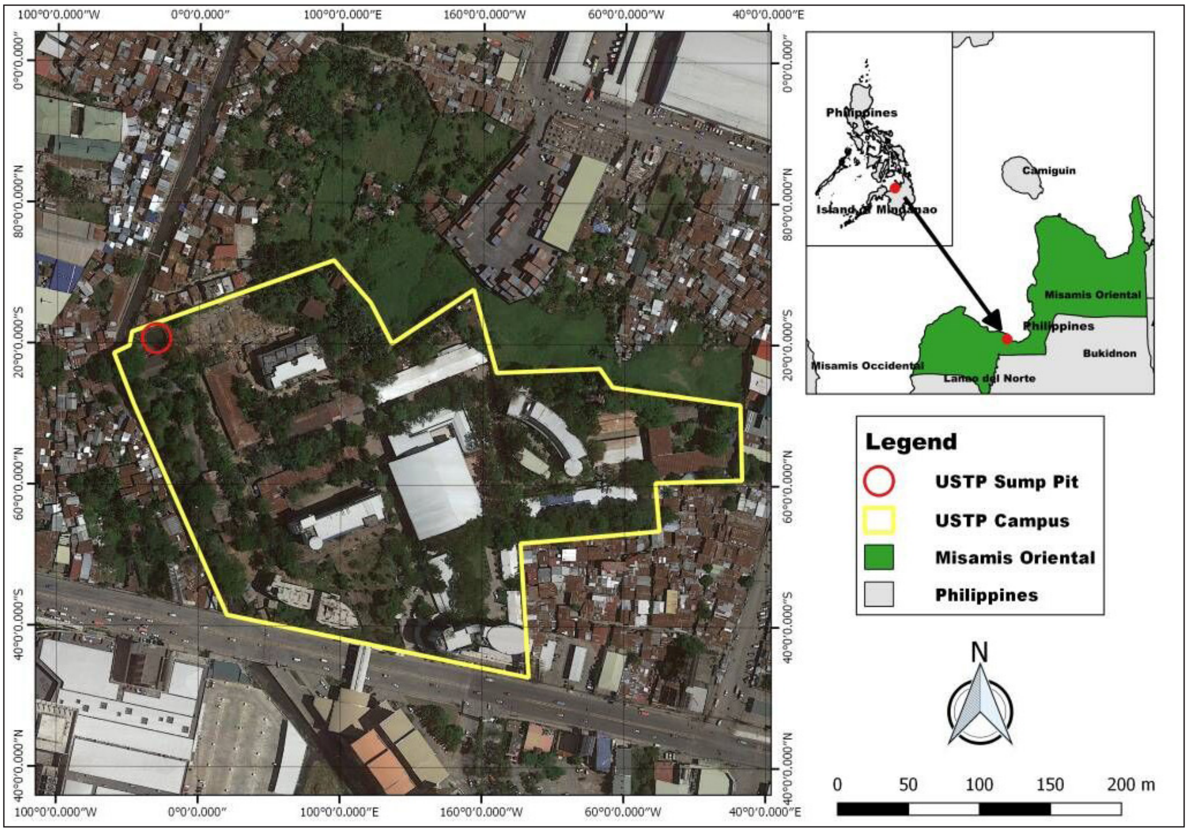

Figure 1. The layout of the study area.

minutes. Finally, it was ground by using a mortar and pestle and sieved to a size between 90-125 μm. The powder from the Saluyot leaf was kept in a tight container ready for use. **Figure 2** showed the experimental setup in the preparation of saluyot powder, and the final product is shown in **Figure 3**.

$$\text{Yield of polysaccharide }(\%) = \frac{\text{Weight of polysaccharides }(\text{g})}{\text{Weight of raw material }(\text{g})} \times 100$$

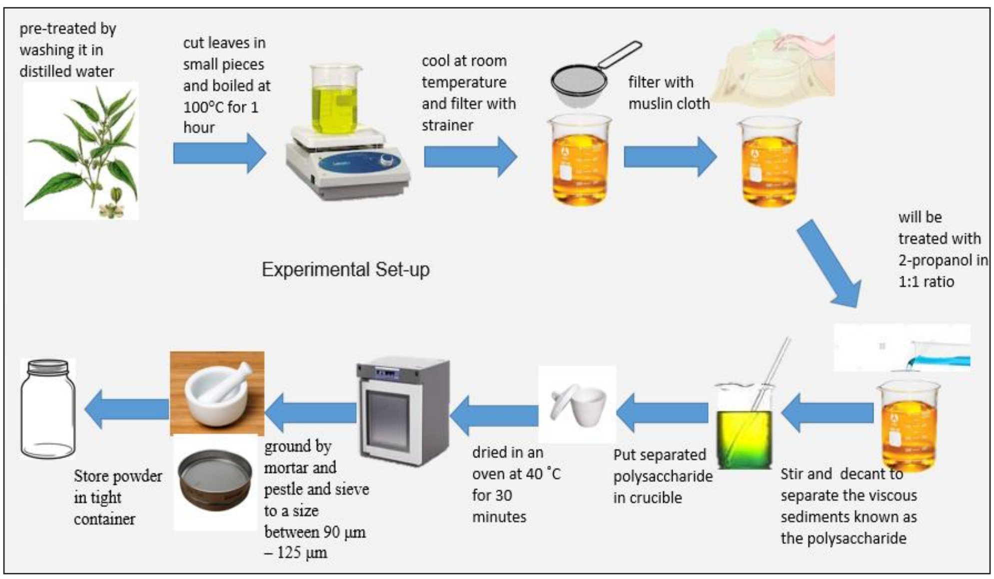

Figure 2. Flow chart diagram of saluyot powder preparation.

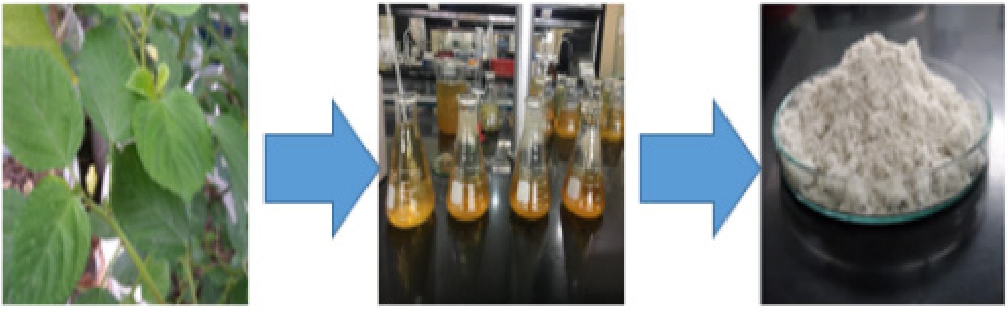

Figure 3. Chart showing the final product after the preparation.

Table 1 showed the characteristics of *Corchorus olitorius L.* (Saluyot), according to total carbohydrate, crude protein, crude fiber, crude lipid, and ash in mg/g, in both leaves and stems, as adapted from Ndovu and Afolayan 2008 [8].

The physical characteristics of *Corchorus olitorius L.* (Saluyot) mucilage powder (**Table 1**) are determined by its color, odor, texture, and solubility. Chemical characteristics are analyzed using Fourier-transform infrared spectroscopy (FTIR).

Characterization of Corchuros olitorius L. mucilage

Fourier-transform infrared spectroscopy (FTIR) is an analytical technique used to identify organic or inorganic materials. The method of analysis involving FTIR used infrared light to scan test samples and observe chemical properties. The FTIR instrument sends infrared radiation of about 10,000 cm^{-1} to 100 cm^{-1}. Some radiation is absorbed and some are passed through, in which absorbed radiation is converted into vibrational energy by the sample molecules [9-11]. The resulting signal presents a spectrum that represents the molecular fingerprint of the sample. This technique is useful in analyzing the chemical composition of substances. In this study, the powder sample of *Corchorus olitorius L.* (saluyot) mucilage was subjected to FTIR analysis to determine a functional group of these substances that influenced the coagulation property.

2.4 Jar test and optimization of synthetic and bio-coagulant

Analysis of the optimum dosage of synthetic and bio-coagulant was done using a jar test. **Figure 4** below showed the flow chart diagram of the jar test design with different treatment combinations using the bio-coagulant *Corchuros olitorius L.* and synthetic coagulant, aluminum sulfate.The purpose of the jar test is to determine the optimum dosage/concentration of each coagulant to be used for the treatment design as shown in **Table 2**. The jar test for each coagulant (Alum and *Corchuros olitorius L.*) was done separately. Each coagulant dose varies at 50 mg/L, 100 mg/L, and 150 mg/L while stirring speed was also varied at 550 rpm at a 3-minute contact time followed by 200 rpm at 7 minutes for each dose. After the jar test, the optimum dose for each coagulant was used in the treatment design experiment using the same volume of wastewater sample. The aluminum salt and *Corchuros* mucilage were treated separately at various pH conditions namely: pH = 5, pH = 7, pH = 9; while contact time and varying stirring speed at 550 rpm for 3 minutes followed by 200 rpm at 7 minutes. It was then allowed to settle separately at different settling times, between 30 minutes, 60 minutes, and 90 minutes. The same process was applied to the control during the actual treatment (**Table 2**) using different percent coagulant mix. Af-

Table 1. Characteristics of *Corchorus Olitorius L.* (Ndovu and Afolayan 2008).

	Total carbohydrate, mg/g	Crude Protein, mg/g	Crude Fiber, mg/g	Crude Lipid, mg/g	Ash, mg/g
Leaves	695.0 ± 32.4	162 ± 3.4	20.3 ± 1.0	17.2 ± 2.9	105.2 ± 1.0
Stems	802.0 ± 18.2	51.0 ± 1.8	88.2 ± 4.8	69.0 ± 1.3	51.9 ± 1.2

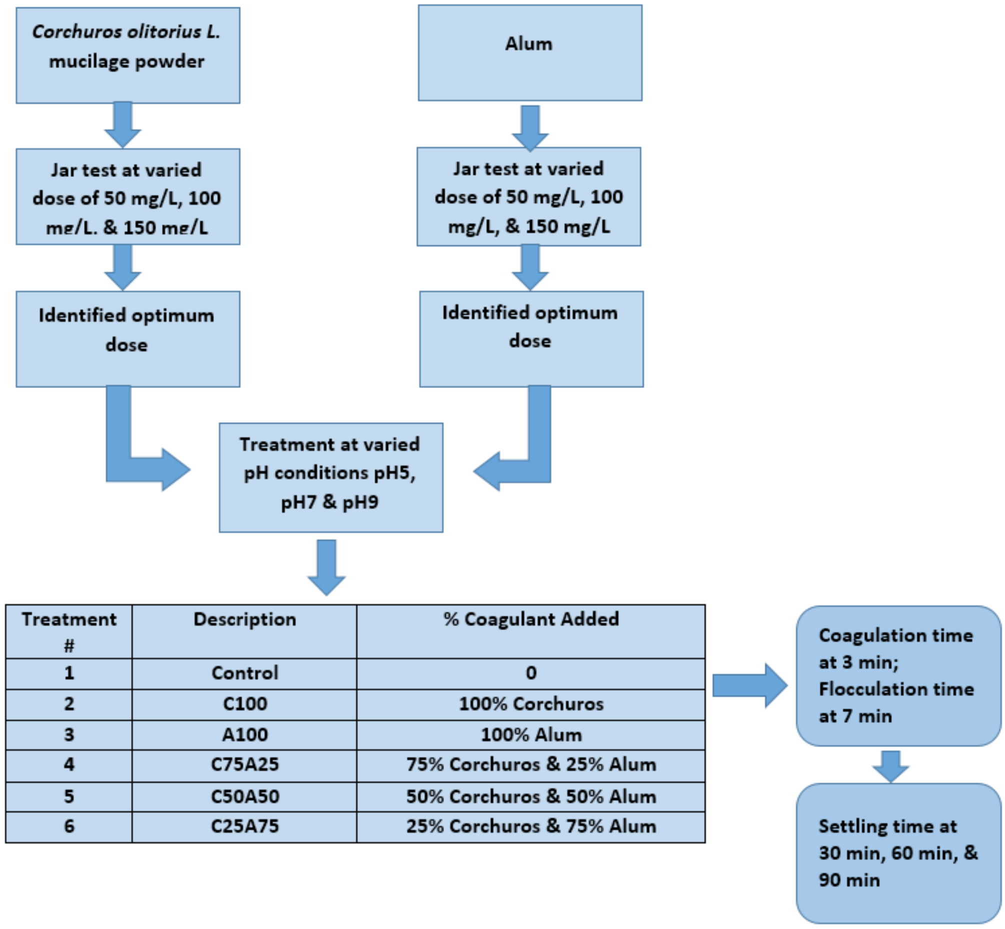

Figure 4. Flowchart diagram of jar test optimization and treatment design.

Table 2. Field layout of various coagulant optimum doses.

Treatment #	Description	% Coagulant added
1	Control	0
2	C_{100}	100% Corchuros
3	A_{100}	100% Alum
4	$C_{75}A_{25}$	75% Corchuros & 25% Alum
5	$C_{50}A_{50}$	50% Corchuros & 50% Alum
6	$C_{25}A_{75}$	25% Corchuros & 75% Alum

ter sedimentation, following various settling times, the supernatant liquid was collected by decantation and analyzed for turbidity, TSS, and BOD. The coagulant dose that gives the best results in the reduction of the selected water quality parameters, was the optimum dose. All experiments were performed at room temperature (22 ± 1 °C) and the pH of the samples was tested before and after the addition of the coagulant to adjust it to its desired pH. After the jar test, the optimum dose for each coagulant was used to conduct the experiment applying the described treatment design as shown in **Table 2**.

2.5 Analysis of treated effluent

After the treatment of water samples using the coagulation-flocculation procedures, the supernatant liquid was subjected to analysis for the determination of final turbidity, total suspended solids (TSS), and biochemical oxygen demand (BOD). Turbidity was measured using a digital turbidity meter which was calibrated prior to the test. Total suspended solids were analyzed by the use of the gravimetric method. Filtration of the treated effluent with TSS filtration apparatus followed by a series of heating and weighing until the constant mass is achieved. While BOD was measured using the dilution technique.

3. Results and discussions

3.1 Characterization of *Corchuros olitorius L.*

Corchuros olitorius L. is characterized according to its physical and chemical characteristics. Chemical characteristics involve the FTIR analysis in determining the possible functional group which is the reason for its coagulative property.

Physical & chemical characteristics of Corchuros olitorius L.

Table 3 showed the physical and chemical characteristics of saluyot mucilage powder. It is grayish-white in color, odorless and fibrous, and is insoluble with alcohol. *Corchorus olitorius L.* (Saluyot) waste can be considered a natural polymer. When used as a coagulant or coagulant aid, it enables the formation of chemical bridges, through hydrogen bonds or van der Waals forces, with the suspended solids in the treated water. This will enhance the flocculation process [12].

Table 3. Identification test results of *Corchuros* mucilage.

Identification Test	Characteristics
Color	grayish white
Odor	Odorless
Texture	Fibrous
Alcohol precipitation test *	Gelatinous precipitate
Thorium Nitrate test *	Cloudy gel
Sodium hydroxide test *	Translucent soft gel
Without Heating *	Voluminous precipitate
With Heating *	Floating turbid mass
% degree of esterification *	49.44
% total anhydrogalacturonides *	74.31
Computed molecular weight (g/mole) *	1700
Solubility	Insoluble with alcohol

*Adapted from Montano et al., 1997.

The high carbohydrate content of saluyot, presenting the carboxyl and hydroxyl groups, increases the clotting ability. Though it is not extensively reported in the open literature, it is highly possible that galacturonic acid [a major constituent of pectin in plants] exists predominantly in the polymeric form [polygalacturonic acid] that provides a 'bridge' for particles to adsorb on. The polygalacturonic acid structure evidently indicates that it is anionic due to partial deprotonation of carboxylic functional group in an aqueous solution. The existence of such functional groups along the chain of polygalacturonic acid implies that chemisorption between charged particles and –COO− may occur although this requires further empirical substantiation [12]. The presence of –OH groups along its polymeric chain also infers possible intramolecular interactions which may distort the relative linearity of the chain [13]. It is believed that the presence of hydroxyl groups along the polymer chain provides abundant adsorption sites for the removal of suspended particles in water [14]. Previous studies revealed that the physical and chemical properties of natural substances have contributed to the effect of their coagulation characteristics.

FTIR analysis of Corchuros olitorius L. (Saluyot) mucilage powder

The potential active functional groups in saluyot powder were characterized using Fourier-transform Infrared Spectroscopy (FTIR). It was found that saluyot powder possibly contained –OH, –NH, and C = O functional groups that indicate good potential as a natural coagulant [15]. Although the fingerprint region did not show two peaks somewhere 1050 cm^{-1}, there are studies [15-19] that reveal the presence of hydroxyl as a functional group in saluyot mucilage powder. The FTIR spectra of saluyot mucilage is shown in **Figure 5**. Small but sharp peaks were visible between 1600-1000 cm^{-1} and low peaks at 3400-2900 cm^{-1} which are indicative of phenols and carbonyl stretching. The active groups are a boost to bind and react to form flocs. In the spectrum, it shows adsorption bands between 1550 cm^{-1} to 1050 cm^{-1} indicative of N-O stretching and C-O-C stretching.

Other observations showed a medium peak from 1650 cm^{-1} to 1550 cm^{-1} signifying that the compound could be C = N and C = C bond at 1600 to 1680 wavenumber. There is a somewhat weaker peak at 3050 cm^{-1} to 3200 cm^{-1} indicative of OH stretching. It signifies that a compound could possibly have alcohol content, however, the peak is so weak may be due to the absence of a homogeneous powder sample during preparation. However, studies revealed that the major functional group associated with *Corchorus olitorius L*. mucilage is attributed to the presence of phenolic content [16,17,20,21].

These bands are quite similar to other natural coagulant aid used in the coagulation process [18]. Saluyot mucilage powder has a higher molecular weight which explains its viscosity [19]. **Figure 5** showed the FTIR results with the characterization of the *Corchuros olitorius L.* mucilage powder.

It has been stated from works of literature that the presence of esters or hydroxyl groups could be the reason for boosting the coagulant capability of saluyot. A study by Baang et al. [16] indicated that among the five vegetables being sampled for total phenolics, *C. olitorius L.* (saluyot) ranks the highest phenolic content with an amount of 6.15 mg/gram of dried sample. Additionally, with the DPPH free radical scavenging activity, *C. olitorius L.* ranks second with a value of 63.76% among the five (5) plants being studied.

Plant-based natural coagulants could be a worthwhile alternative in addressing the environmental and ecological concerns raised over the usage of chemical coagulants in water clarification [17]. It is likely that synergistic effects between the polypeptides and polysaccharides in natural coagulants have resulted in the observed coagulation activities.

3.2 Optimization of *Corchuros olitorius L.* (C_{100})

Coagulant optimization using *Corchorus olitorius L.* is done in the same process as other coagulants. A stock solution of *Corchorus olitorios L.* is freshly prepared before the experiment. A 100% *Corchorus olitorios L.* stock solution (C_{100}) at different alum dosages of 50 mg/L, 100 mg/L, and 150 mg/L was also used to treat a 50 mL wastewater sample at a similar ratio.

As shown in **Figure 6**, the percentage of turbidity removal was found to be optimum with a lower dosage level of 50 mg/L for the settling time of 90 minutes for all pH conditions of pH 5, pH 7, and pH 9. The maximum amount of removal percentage obtained for turbidity was 70.21%, 68.99%, and 62.31% at turbidity of 9.8 NTU, 10.2 NTU, and 12.4

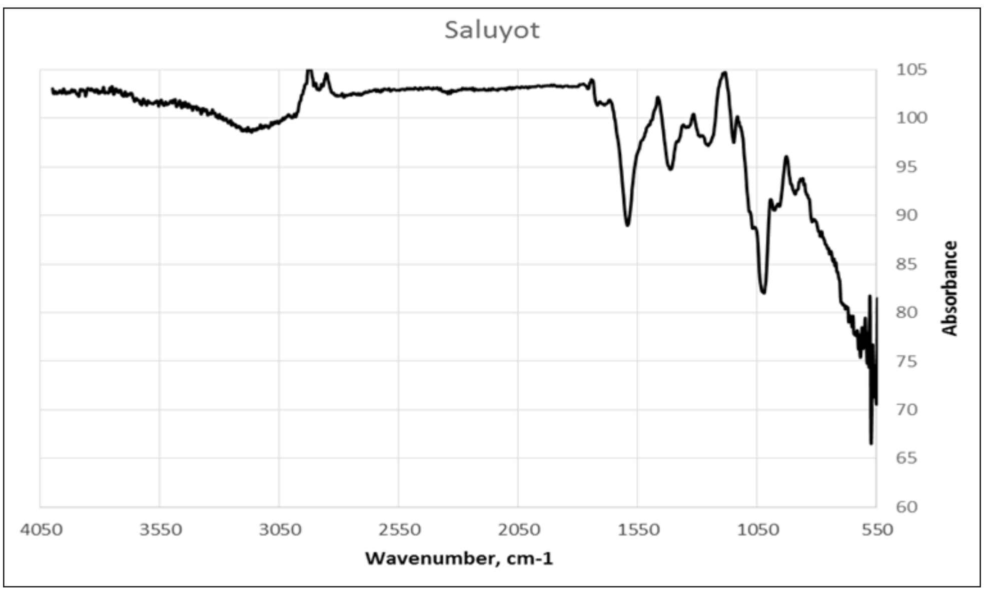

Figure 5. FTIR spectra of *Corchuros* mucilage powder.

NTU at pH 5, pH 7 & pH 9 with a turbidity of control at 32.9 NTU. The results of turbidity removal, when saluyot coagulant dosage was increased to 100 mg/L, showed a lower removal at values of 50.15% (pH 5, 30 min), 58.87% (pH 5, 60 min), 60.47% (pH 5, 90 min); 48.94% (pH 7, 30 min), 51.06% (pH 7, 60 min), 55.62% (pH 7, 90 min); 39.21% (pH 9, 30 min), 42.86% (pH 9, 60 min), and 49.24% (pH 9, 90 min).

Further increase of saluyot coagulant dosage to 150 mg/L further reduced the turbidity removal with measured values of 47.42% (pH 5, 30 min), 48.63% (pH 5, 60 min), 51.38% (pH 5, 90 min); 36.78% (pH 7, 30 min), 40.73% (pH 7, 60 min), 48.02% (pH 7, 90 min); 30.69% (pH 9, 30 min), 35.56% (pH 9, 60 min), & 38.29% (pH 9, 90 min). It is observed from the results that changing the coagulant dosage and settling time had an effect on the turbidity removal from wastewater.

Figure 7 showed the results of the optimization of coagulant *Corchorus olitorius L.* when total suspended solid (TSS) is used as a water quality parameter to determine the maximum removal. When at first, the coagulant dosage was 150 mg/L, TSS results were 50.64%

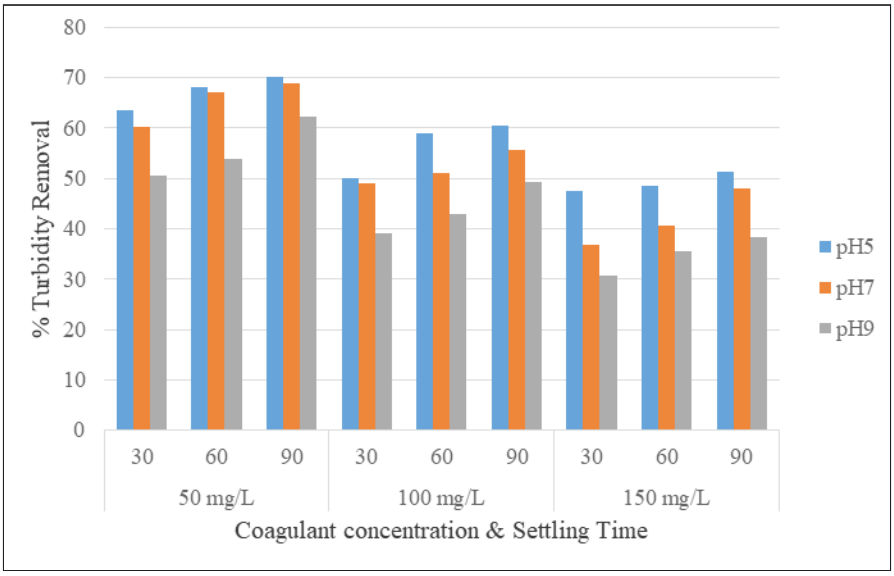

Figure 6. Optimization of coagulant *Corchorus olitorius L.* with turbidity.

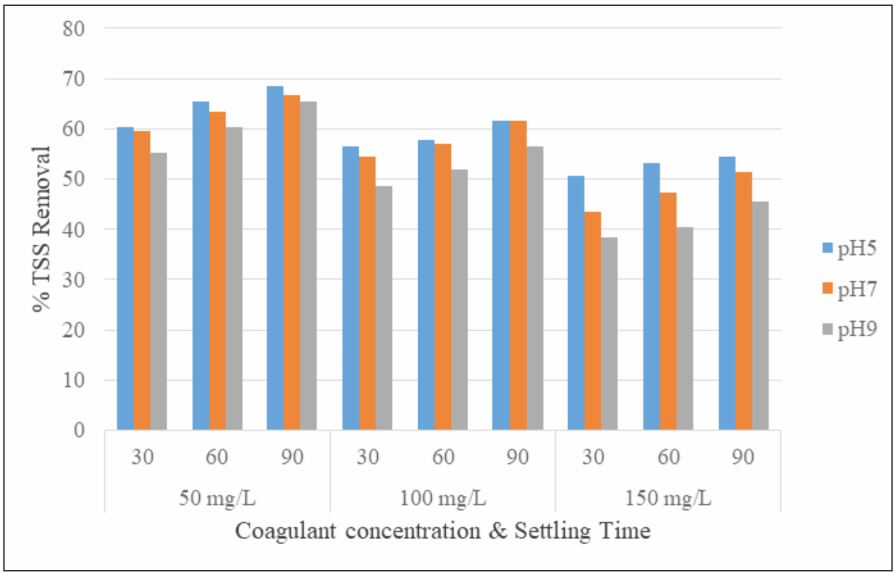

Figure 7. Optimization of coagulant *Corchorus olitorius L.* with TSS.

(pH 5, 30 min), 53.21% (pH 5, 60 min), 54.48% (pH 5, 90 min); 43.59% (pH 7, 30 min), 47.44% (pH 7, 60 min), 51.28% (pH 7, 90 min); 38.46% (pH 9, 30 min), 40.38% (pH 9, 60 min), and 45.51% 45.51% (pH 9, 90 min). When saluyot coagulant dosage was decreased to 100 mg/L, results were 56.41% (pH 5, 30 min), 57.69% (pH 5, 60 min), 61.54% (pH 5, 90 min); 54.49% (pH 7, 30 min), 57.05% (pH 7, 60 min), 61.54% (pH 7, 90 min); 48.72% (pH 9, 30 min), 51.92% (pH 9, 60 min), 56.41% (pH 9, 90 min). There is an increase in the TSS removal when coagulant dose was lowered.

Further decrease of saluyot coagulant dose to 50 mg/L resulted to TSS removal of 60.25% (pH 5, 30 min), 65.38% (pH 5, 60 min), 68.59% (pH 5, 90 min); 59.62% (pH 7, 30 min), 62.46% (pH 7, 60 min), 66.67% (pH 7,90 min); 55.13% (pH 9, 30 min), 60.26% (pH 9, 60 min) and 65.38% (pH 9, 90 min). It showed from the results that as the saluyot coagulant dose was reduced, there is an increase in the TSS removal.

Figure 8 showed the results of *Corchorus olitorius L.* optimization when biochemical oxygen demand (BOD) was used as the parameter to evaluate. It revealed that the lowest coagulant dose of 50 mg/L and settling time of 90 minutes attained the highest BOD removal of 72.12%, 70.22% & 67.74% at pH 5, pH 7 & pH 9 respectively.

Statistical analysis using two-way analysis of variance indicated with p-values less than 0.05 ($p < 0.05$) that the means of observations between coagulant dosage and settling time significantly differ. The percentage removal of the five (5) parameters varies with coagulant dose and time of particle settling.

When *Corchorus olitorius L.*, was tried as the primary coagulant it also removed pollutants successfully. The parameters TSS, turbidity, nitrogen, phosphorus, and BOD were observed significantly less after the treatment of water. For 50 mg/L, 100 mg/L, and 150 mg/L doses of 100% *Corchorus olitorius L.* stock solution (C_{100}), the measured values of the parameters were reduced as compared to its control, and removal of pollutants is evident and highest at a lower concentration of 50 mg/L and with higher settling time of 90 minutes. Percent removal showed that as the dosage is increased from 50 to 100 and 150 mg/L, measured values increase and percent removal diminishes with increased dosage and shorter settling time respectively. Settling time at 90 minutes resulted in a higher reduction of turbidity, TSS, nitrogen, phosphorus, and BOD. This is attributed to the presence of high concentrations of both carbohydrates and lipids in the stems which can increase the content of organic matter in the treated water and represents a disadvantage due to the increase in turbidity in certain situations if the dose of the primary

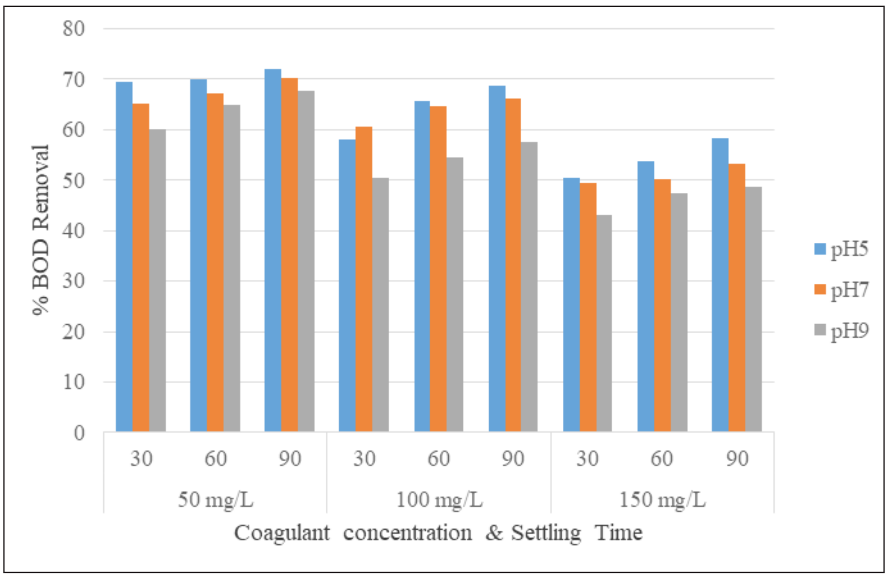

Figure 8. Optimization of coagulant *Corchorus olitorius L.* with BOD.

coagulant is not well adjusted [20]. When *Corchorus olitorius L*. was tried as a sole coagulant, removal of turbidity was poor as compared to alum [21]. An explanation is a steric hindrance that takes place between polymer molecules at high concentrations [22].

3.3 Removal efficiency of turbidity, TSS & BOD

Turbidity

Table 4 showed the results of turbidity removal when wastewater was treated with a coagulation-flocculation process under three (3) pH conditions (pH 5, pH 7 & pH 9).

Table 4. Percent removal efficiency of turbidity.

Treatment	pH 5	pH 7	pH 9
A_{100}	97.81	98.14	98.31
C_{100}	70.48	67.62	62.23
$A_{50}C_{50}$	84.49	84.15	85.33
$A_{25}C_{75}$	82.12	80.27	82.97
$A_{75}C_{25}$	85.16	83.47	85.67

Data revealed that with the use of 100% alum (A_{100}) solution, turbidity removal was highest at pH 9 with a removal percentage of 98.31%. A study also reported that when Alum was used to treat wastewater containing Acid Red 398 dye solution by coagulation/flocculation process, it also removed 80% of turbidity at 140 mg/L of alum [23].

On the other hand, a 100% *Corchorus* solution (C_{100}) at an optimum dose of 50 mg/L operating at an optimum settling time of 90 minutes obtained removal efficiency of 70.48%, 67.62%, and 62. 23% at pH 5, pH 7, and pH 9. When treatment was done involving coagulant aid mixing; 50% *Corchorus* with 50% alum ($A_{50}C_{50}$) treatment at the optimum dose and optimum settling time obtained removal efficiency of 84.5%, 84.2%, and 85.3% at pH 5, pH 7, and pH 9. Additionally, a 75% *Corchorus olitorius L*. and 25% alum stock solution ($A_{25}C_{75}$) treatment at an optimum dosage level of 50 mg/L and optimum settling time of 90 minutes obtained a maximum amount of removal percentage of 82.1%, 80.3%, and 82.9%. Similarly, 25% *Corchorus olitorius* and 75% alum stock solution ($A_{75}C_{25}$) treatment at an optimum dosage level of 50 mg/L and optimum settling time of 90 minutes obtained a maximum amount of removal percentage 85.2%, 83.5% and 85.7% for pH level 5, 7 and 9 respectively. It showed that with *Corchorus* as the coagulant aid highest removal was observed at $A_{75}C_{25}$ at pH 9.

Results, as shown, indicated that removal efficiency varies with treatment designs under optimum coagulant dose and settling time. The magnitude differs for a particular coagulant and pH conditions [24,25]. The other natural coagulants have minimal effect on changes in pH conditions [26].

Total suspended solids (TSS)

Table 5 presented results for the removal efficiency of total suspended solids after wastewater has been treated with coagulant and coagulant aids with different treatment designs. As shown in the results, a treatment combination containing 50% *Corchorus olitorius L.* and 50% alum ($A_{50}C_{50}$) obtained removal efficiency of 88.8%, 87.2%, and 86.6% for pH 5, pH 7, and pH 9 treatment conditions.

Table 5. Percent removal efficiency of TSS.

Treatment	pH 5	pH 7	pH 9
A_{100}	95.9	96.8	98.4
C_{100}	68.45	67. 65	65.51
$A_{50}C_{50}$	88.77	87.16	86.63
$A_{25}C_{75}$	86.7	85.56	85.56
$A_{75}C_{25}$	89.57	88.5	87.43

Furthermore, a treatment containing 75% *Corchorus* and 25% alum ($A_{25}C_{75}$) resulted in removal percentage of 86.7% for pH 5 and 85.6% for pH 7 & pH 9; whilst treatment combination with 25% *Corchorus* and 75% alum ($A_{75}C_{25}$) obtained removal efficiency at 89.6%, 88.5% & 87.4%.

Biochemical oxygen demand (BOD)

Table 6 has shown results of the removal efficiency of the biological water quality parameter, BOD when wastewater was subjected to a coagulation-flocculation process using treatment designs.

When alum was mixed with *Corchorus oiltorius L. as* a coagulant aid, BOD removal efficiency was observed at 89.70% at pH 5, 88.76% at pH 7 & 86.28% at pH 9 with $A_{50}C_{50}$. Similarly, with a treatment design containing 75% *Corchorus* ($A_{25}C_{75}$) removal efficiency attained was 86.72% at pH 5, 85.98% at pH 7 & 83.50% at pH 9; whilst at 25% *Corchorus* ($A_{75}C_{25}$) BOD removal was obtained was 90.23% at pH 5, 89.78% at pH 7 and 87.44% at pH 9.

Table 6. Percent removal efficiency of BOD.

Treatment	pH 5	pH 7	pH 9
A_{100}	94.89	95.62	97.81
C_{100}	71.97	70.51	68.61
$A_{50}C_{50}$	89.78	88.76	86.28
$A_{25}C_{75}$	86.72	85.98	83.5
$A_{75}C_{25}$	90.23	89.78	87.44

Lastly, results also revealed that BOD removal efficiency decreases with pH when the coagulant used was *Corchorus.* Like any other bio-coagulant, *Corchorus* showed potential in the removal of contaminants in water. By using a natural coagulant, there was substantial removal of BOD [27] at more than 50% as compared to the conventional treatment process [28].

4. Conclusions and recommendations

The results of the characterization of *Corchuros olitorius L.* (Saluyot) showed that the mucilage composition of saluyot powder has influenced the coagulation activity. Furthermore, the results of the study proved that optimum doses of coagulant aid *Corchorus olitorius L.* reduced contaminants. Coagulation experiments with this bio-coagulant indicated that the coagulation-flocculation process effectively removed turbidity, TSS & BOD from the wastewater using the optimum dosage. In general removal efficiency of most contaminants in water was highest at pH 5 for *Corchorus olitorius L.* and decreases with the increase in pH. Statistical evidence showed significant differences in the measured values among treatment designs with optimum dose and the effect between pH in removal efficiency in all treatment designs is insignificant. As a whole, it can be concluded that the usage of bio-coagulant *Corchuros olitorius L.* would considerably save the use of chemicals and reduced impacts associated with health risks. Additionally, it is recommended that further efforts could be made to improve the removal efficiency of the contaminants under study by enhancing other variables such as mixing intensity and contact time between the water and coagulant, as well as other factors.

Conflict of Interests

The authors declare no conflict of interest.

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