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Turbidity reduction of abattoir wastewater by the coagulation-flocculation process using papaya seed extract

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ABSTRACT

Abattoir wastewater (ABW) is a major environmental pollutant in Nigeria and from its characteristics, if discharged directly to the environment, constitute a hazard to human life and aquatic life. The utilization of a locally available waste, papaya seed, as a source of bio-coagulant for the treatment of abattoir wastewater was examined in this research. To identify the optimum concentration for the extraction process, experiments were carried out utilizing 0.2, 0.6, 1.0, 2.0, and 4.0 M of NaCl, 1 g/L dose of the coagulant and natural pH of the Abattoir effluent. FTIR (Fourier Transformed Infrared) analysis was employed to determine the functional groups available in the extracted bio-coagulant. To establish the optimal coagulation conditions, the effects of process variables such as coagulant dosage (1 – 5 g/L), settling time (0 – 60 min), pH (2 – 10), and temperature (298 – 318K) were examined. Reduction efficiency of 91.38% was achieved at an optimum condition of 3 g/L, pH of 8, temperature of 318K and settling time of 20 min. The coagulation Kinetics studies were also carried out, which revealed that the process fitted well into the second-order coagulation reaction rate with a correlation coefficient of 0.898, coagulation rate constant of 0.00002 L/mg-min and coagulation time of 48.24 min. The study, therefore, revealed that extract from Papaya seed can effectively be used for turbidity reduction of Abattoir wastewater.

Keywords: Turbidity, Abattoir, Papaya seed, Coagulant, Kinetics.

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1. INTRODUCTION

Water is vital to any ecosystem, as it is to human health and well-being, as well as to economic growth (WHO and UN-Habitat, 2018). According to Kang and Trevino (2017) freshwater is important to abate series of global challenges from health, malnutrition, poverty and to ensure sustainable natural resources management. It was estimated at the global level, that the diseases from water, sanitation and hygiene have a huge impact on the total disease burden with a major concern on diarrheal disease, resulting in 4.0% (2,213,000) of all deaths and 5.7% (82,196,000) of the total disease burden worldwide (Purss et al., 2002). In regions where water is scarce, untreated wastewater discharge to river sources causes water pollution, thereby limiting the opportunity for safe, productive use and reuse of such water sources to augment freshwater supplies (WHO and UN-Habitat, 2018).

Turbidity in water is a result of silt, bacteria, algae, viruses, macromolecules and materials derived from organic soil matter, minerals etc. (Bratby, 1980). Abattoir wastewater composes mainly of fats, proteins, pathogens and high organic contents. This wastewater, if it is discharged directly into the environment without treatment, causes degradation of land, affect aquatic life, source of diseases and death to human life.

There is also the possibility of transmission of pathogens to humans (FAO, 2019). Therefore there is a great need for abattoir wastewater to be treated at the source before discharge into the environment.

In water treatment, inorganic coagulants of Aluminium and iron salt are commonly used, as a result of being readily available and low cost, but these inorganic coagulants have the disadvantage of a high volume of sludge formation, a big drop in the pH of the water and possibility of causing Alzheimer disease from excessive intake of Alum (Khodapanah et al., 2013). This has spurred a surge interest in organic coagulants which are biodegradable, less costly, easily available, and ecologically benign, such as Moringa seed (Ghebremichael et al., 2005; Kang and Trevino, 2017), Okra pod (Okolo et al., 2015), Papaya seed (Chandran and George, 2015; Kang and Trevino, 2017), Cottonseed (Weberich et al., 2016) Pumpkin seed (Kang and Trevino, 2017).

The primary phase in the production of natural coagulants is to wash, dry, grind, and use the powdered form of the plant material directly in wastewater treatment (Yin, 2010). This method of processing has a high efficiency for low turbid water (Chandran and George, 2015). The powdered form of papaya seed has been reported for river treatment (Chandran and George, 2015), irrigation canal treatment (Kang and Trevino, 2017), and municipal wastewater treatment (Maurya and Daverey, 2018). They reported that increasing the dosage of the coagulant resulted in high turbidity removal efficiency of the coagulant up to a certain point, after which a negative impact on the turbidity was observed, which is as a result of the coagulants being rich in plant material, which increases the organic loads in the treatment of the wastewater, thereby increasing the turbidity (Ghebremichael et al., 2005). The secondary step is an improvement of the primary step, it involves extracting the active component necessary for coagulation from the ground material in the primary step using either water, organic or salt solution (Yin, 2010). Okuda et al. (1991) discovered that coagulants prepared with 1 M of NaCl salt solution were 7.4 times better than those prepared with distilled water in the extraction of the active component from Moringa seed. Brima et al. (2013) used water and five different types of salt in the extraction of coagulants from peanut seeds for the treatment of turbid water, he discovered that the coagulating ability of the coagulants extracted with salts was 8.3 times better than that of distilled water.

Previous research (Chandran and George 2015, 2018; Kang and Trevino 2017; Maurya and Daverey, 2018), investigated and found the usefulness of Papaya seed in its raw state for turbidity reduction of low turbid water. In this study, NaCl salt solutions were used to extract the active component of the Papaya seed in order to determine the optimum concentration of NaCl that could be used in the extraction process. The effect of dosage, pH, settling time, and temperature variation on the rate of turbidity reduction of abattior wastewater was studied, as well as the kinetics.

2. MATERIALS AND METHODS

2.1 Abattoir Wastewater

The abattoir wastewater (ABW) was collected from Kwata Abattoir in Awka Anambra State, Nigeria and preserved at 4°C to reduce the rate of degradation of the sample. The Physico-chemical properties of the ABW were determined using the standard methods for determining the quality of water and wastewater (APHA, AWWA and WEF, 1999).

2.1.1 Preparation and Deoiling of Papaya Seed Powder

The Papaya seed as shown in Fig. 1(a) was collected from fruit sellers at Eke Awka Market, Anambra State Nigeria. Dried under the sun for seven days, pulverized and stored in an airtight plastic container. The pulverized sample was de-oiled using the method of Gidde et al. (2012), the sample was soaked in ethanol in the ratio of 1:10 (w/v), stirred for 20 minutes using a magnetic stirrer, the supernatant was separated from the mixture using a filter paper, dried at room temperature and stored for further use.

2.1.2 Extraction of Coagulant

The active component in the pulverized de-oiled sample as shown in Fig. 1(b) was extracted using varying concentrations of sodium chloride solution (0.2, 0.6, 1.0, 2.0 and 4.0 M) in the ratio of 1:10 (w/v), stirred for 30 minutes using a magnetic stirrer. The resultant mixture was filtered using Whatman filter #3, the filtrate was heated at 70°C for 5 minutes while stirring, to ensure no white precipitate was formed and then filtered again. The filtrate was further concentrated at 70°C, dried at room temperature for 24 hours and the dried coagulant (PSC) as shown in Fig. 1(c) was crushed and stored in an airtight container for the coagulation process. FTIR (Fourier Transformed Infrared) analyses were carried out using Buck scientific infrared Spectrophotometer (Model 530, England) on the extracted active component to determine the functional groups present in the PSC using Mid-Spectrum (400 – 4000 1/cm).

Fig. 1. (a) Dried Papaya Seed (b). Pulverized Papaya seed (c). PSC

2.1.3 Coagulation Jar-Test Experiment

For the coagulation experiment, Conventional Jar test apparatus was employed. Following the method of Okolo et al. (2015), 1 g of various coagulants extracted with different concentrations of NaCl (from section 2.12) were added to 1000ml of Abattoir wastewater at ambient temperature and natural pH of the effluent, and the wastewater and coagulants were stirred for 2 minutes at 250 rpm for rapid mixing and 20 minutes at 30 rpm for slow mixing. The stirrer was turned off at the end of the gradual mixing, and 20 mL of the supernatant were pipetted from a depth of 2 cm into a 50 mL plastic container, and their residual turbidity was measured with a portable Turbidity meter (Model: WDZ-1B). The optimum concentration of NaCl (determined aboved) was then used to evaluate the effect of dose variation (1 – 5 g) and pH variation (2 – 10), using the same method of Okolo et al. (2015), diluted Hydrochloric acid (HCL) and Sodium hydroxide (NaOH) were used for pH adjustment. The optimum dosage and pH were used to investigate the effect of temperature variation (298 – 318K) and settling time at intervals of 5, 10, 15, 20, and 60 minutes. The percentage of turbidity reduction was calculated using Equation 1 (Weberich et al., 2016)

$$\%R = \frac{C_o - C_e}{C_e} * \frac{100}{1} \quad (1)$$

Where C_0 and C_e are the initial turbidity (untreated wastewater) and final turbidity (treated) of the wastewater (NTU), respectively.

2.2 ABW Coagulation Kinetics Studies

According to the kinetic theory of Maxwell and Boltzmann in Sonntag and Strenge (1987)

$$\frac{1}{2} m\bar{v}^2 = \frac{2}{3} k_B T \quad (2)$$

Where T the absolute temperature, $\bar{v}$ is the average velocity, K_B is the Boltzmann constant (1.38064852 × 10 − 23 J/K), and m is the mass of the molecules.

As particle moves within a liquid, at the surface frictional force (F_R) occurs between the particle and the liquid and it increases as the velocity of the particle increases, for a particle moving with velocity $\frac{dx}{dx}$, the frictional force is given by (Sonntag and Strenge, 1987):

$$F_R = f_s \frac{dx}{dx} \quad (3)$$

Where f_s is the frictional coefficient, he gave the relationship between f_s and diffusional coefficient as:

$$D = \frac{K_B T}{f_s} \quad (4)$$

The frictional coefficient is determined by:

$$f_s = 6\pi\eta a \quad (5)$$

Where a is the particle radius and η is the viscosity. The temperature dependence of the diffusion coefficient, as shown in Equation 4, has a direct impact on the coagulation rate. Also from Equation 5 increase in the viscosity increases the frictional coefficient thereby decreasing the coagulation rates.

Substituting 5 in 4 gives:

$$D = \frac{K_B T}{6\pi\eta a} \quad (6)$$

As two uncharged particles in a suspension, that are in continuous motion approach each other, they are affected by Van der Waals force of attraction. The number of particles that crosses the surface of one sphere per second (ie the particle flux I) is given by Fick's first law (Sonntag and Strenge, 1987) as:

$$I = 4\pi R^2 D \left(\frac{dz}{dr}\right)_{r=R} \quad (7)$$

Where R is the radius of the sphere of action, $4\pi R^2$ is the area within the sphere of action, Z is the particle concentration and r is the centre to centre distance of the particle.

Also given that

$$\left(\frac{dz}{dr}\right)_{r=R} = \frac{Z_o}{R} \quad (8)$$

Where Z_o is the initial particle concentration

Substituting 8 into 7

Therefore

$$I = 4\pi R D Z_o \quad (9)$$

Assuming a monodispersed system:

$$D_{11} = 2D_1 \quad (10)$$

Therefore, combining Equations 9 and 10,

$$I_{11} = 8\pi R D_1 Z_o \quad (11)$$

Therefore for all particles in the system,

$$\frac{dz_o}{dt} = I_{11} = -8\pi R D_1 Z_0^2 = -2k_s Z_0^2 \quad (12)$$

From Equation 12, the coagulation rate equation is of second order and the coagulation rate constant = $2k_s$.

Substituting R = 2a and Equation 10 into 12 and solving for k_s,

$$K_s = \frac{4K_B T}{3\eta} \quad (13)$$

Time for coagulation is determined using:

$$T_{ag} = \frac{1}{4\pi D_1 R_1 Z_0} = \frac{1}{k_s Z_0} \quad (14)$$

The time taken for the number of aggregates (Doublets, triplets and quadruplets) to reach a maximum is given by:

$$t_{max} = \frac{i-1}{2} T_{ag} \quad (15)$$

Hence for doublet:

$$t_{max} = \frac{1}{2} T_{ag} \quad (16)$$

Triplet:

$$t_{max} = T_{ag} \quad (17)$$

Quadruplets:

$$t_{max} = \frac{3}{2} T_{ag} \quad (18)$$

Where K_s is the coagulation rate constant of second-order, according to Von Smoluchowski ($K_s = 6.05 \times 10^{-12} cm^3 \cdot s^{-1}$ at 298 K).

The general form of Brownian coagulation kinetics of monodispersed particles at an early stage is given as (Menkiti et al., 2008):

$$\frac{dc}{dt} = -KC^{\propto} \quad (19)$$

Where C is the Particles concentrations (TSS)
$\propto$ is the order of coagulation reaction.
K is the rate constant of coagulation

Menkiti (2007) as cited by Menkiti et al. (2009) and Igwegbe and Onukwuli (2019) States that " in real practice, $1 \leq \alpha \leq 2$. Based on this, what is required to evaluate K is to determine the line of a better fit between α = 1 and 2, while the experimental data are fitted into the linearised form" Therefore for $\propto = 1$; Equation 13 yields:

$$\frac{dc}{dt} = -KC \quad (20)$$

Integrating with limits and rearranging Equation 14 gives:

$$\text{Ln } C = \ln Co - Kt \quad (21)$$

Where C_t is the particle concentrations at any time t and Co is the initial particle concentrations.
From Equation 15, a plot of ln C against t gives a slope of –K and intercept of ln Co
For $\propto = 2$; Equation 13 yields (Van-Zanten and Elimelech, 1992):

$$\frac{dC}{dt} = -KC^2 \quad (22)$$

Integrating within limits yields:

$$\frac{1}{C_t} = Kt + \frac{1}{C_0} \quad (23)$$

Plot of $\frac{1}{C_t}$ against t gives a slope of K and intercept of $\frac{1}{C_0}$.

According to Van-Zanten and Elimelech (1992) product of Smoluchowski rate constant (Ks) and collision efficiency (ε_p) can also be used to determine the coagulation Coagulation rate constant.

$$\text{ie, } K = \varepsilon_p k_s \quad (24)$$

Coagulation rate constant is also given as (Sonntag and Strenge, 1987):

$$K = 2k_s \quad (25)$$

$$\text{Hence } k_s = \frac{K}{2} \quad (26)$$

Metcalf and Eddy (2003) as cited in Menkiti (2008) gave the relationship connecting Turbidity (NTU) and Total Suspended solid (TSS) (mg/L) as:

$$\text{TSS (mg/L)} = (\text{TSS}_f) \,.\, \text{T} \quad (27)$$

Where TSS = Total Suspended solid
T = Turbidity (NTU)
TSS_f = Factor for converting Turbidity to TSS.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Abattoir Wastewater

The Abattoir wastewater analysis as presented in Table 1, reveals that the parameters measured exceed that of the standards for the discharge of effluent into water or on land (Kajura, 1999; Odey, 2009 and EWURA, 2014), hence the need for the wastewater to be treated before discharge.

The characterisation of the ABW sample before and after the coagualtion process demonstrates the effectiveness of the PSC in reducing ABW turbidity, as there was a 91.38% reduction in ABW turbidity with comparable reductions in COD, BOD, and TSS.

3.2 FTIR Characterization of the Coagulant

The FTIR of the coagulant presented in Fig. 2 was compared with the standard IR Spectrum Table and Chart (IR Spectrum Table & Chart, 2020) to identify the functional groups in the coagulant. At the single bond region (2500 – 4000 1/cm), the presence of –OH group stretching of alcohol was identified at absorption band centres of 3582.985 1/cm, 3208.687 1/cm and 3091.44 1/cm. At broadband centres of 3371.634 1/cm and 2966.54 1/cm –NH group bending reveals the presence of aliphatic primary amine and amine salt.

At the region of double bond (1500 – 2000 1/cm) –CH group bending of an aromatic compound and –NH bending of primary amine was identified at 1898.831 and 1618.041 1/cm. At the fingerprint region of 600 – 1500 1/cm, the presence of – CN group stretching at 1321.743 1/cm and 1211.674 1/cm reveals the presence of aromatic primary amine and tertiary amine. The presence of –CO bond at 1114.675 1/cm indicates the presence of aliphatic ester and the presence of –CH bending was identified at 847.8492 1/cm and 715.7961 1/cm.

The FTIR analysis reveals that the following functional groups –OH, –NH, –CH, –CN and –CO were in the PSC and are necessary for the high coagulating property of Bio-coagulants, the same was identified by Madhukar and Yogesh (2014) for Moringa Oleifera seed powder; Vishali and Karthikeyan (2014) for Strychnos Potatorum; Menkiti et al. (2018) for Brachystegia Eurycoma extract.

3.3 Effect of Varying Concentrations of NaCl in the Extraction of Coagulant.

From Fig. 3, increasing the concentration of NaCl from 0.2 to 4 M used for the extraction of the active component in the Papaya seed reduces the residual turbidity. The same result was obtained by Brima et al. (2013) for peanut seed, where the residual turbidity decreases with an increase in the concentration of NaCl. As the concentration of NaCl used in the extraction process was increased from 0.1 to 4 M, the residual turbidity decreases from 882 NTU to 200 NTU at 2 M, after which further increase in the concentration of NaCl did not yield a significant result. Therefore, 2 M was taken as the optimum concentration for the extraction.

3.4 Effect of Varying Coagulant Dosage on Turbidity Reduction Efficiency

The type of coagulant and its dosage plays an important role in the treatment of wastewater through the coagulation process, as it determines the mixing time, speed, efficiency and volume of sludge left after the process. According to Menkiti et al. (2016) with the use of optimum coagulant dosage,

Table 1. Characteristic of the Abattoir Wastewater (ABW) and standards for the discharge of effluent into water or on land

Parameter	ABW before the coagulation process	ABW after the coagulation process	Uganda (Kajura, 1999)	Nigeria (Odey, 2009)	Tanzania Standard, (EWURA, 2014)
Turbidity (NTU)	882.0	76.0	300.0	N/A	300.0
COD (mg/L)	346.7	143.0	100.0	250.0	60.0
TSS (mg/L)	2072.7	208.5	100.0	100.0	100.0
TDS (mg/L)	261.0	227.4	1200.0	2100.0	N/A
Conductivity (ms/cm)	202.2	--	N/A	N/A	N/A
Total Hardness (mg/L)	2700.0	--	N/A	N/A	N/A
pH	6.4	6.6	6.0 – 8.0	5.5 – 9.0	6.5 – 8.5
BOD (mg/L)	226.0	95.0	50.0	50.0	30.0
Temperature (°C)	28	35	20 – 35	< 40	20 – 35

EWURA: Energy and Water Utilities Regulatory Authority; N/A: Not Available; COD: Chemical oxygen demand; BOD: Biochemical oxygen demand; TDS: total dissolved solids.

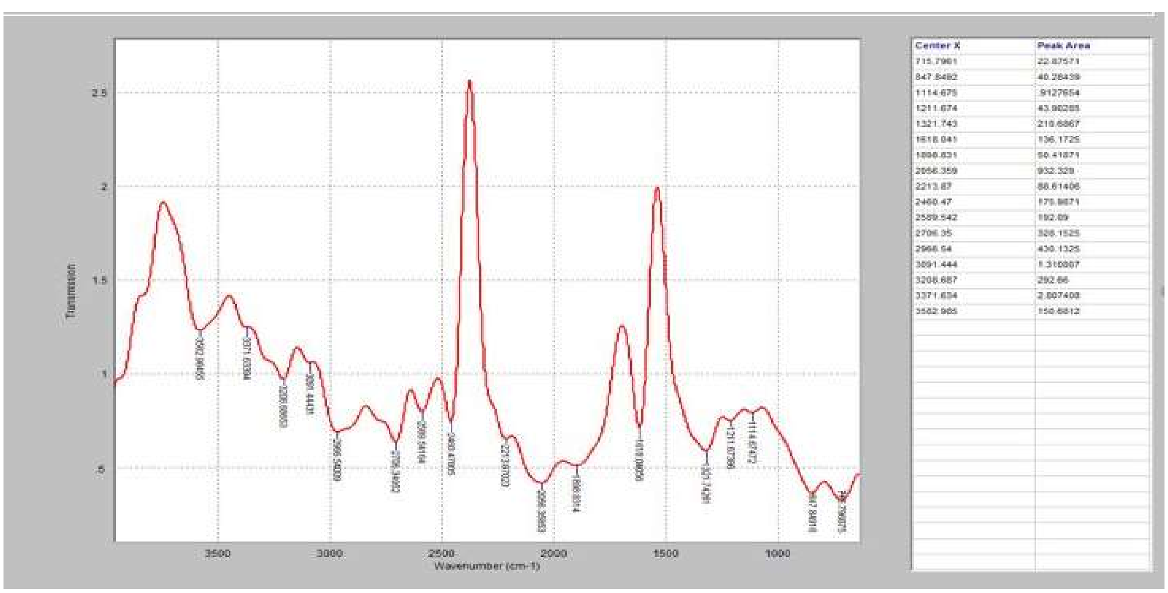

Fig. 2. FTIR Spectrum of PSC

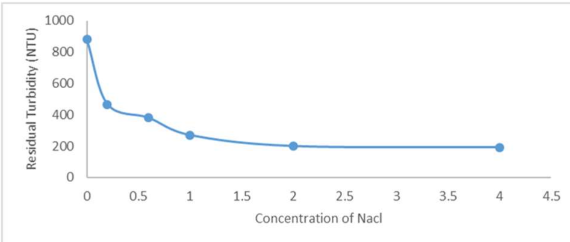

Fig. 3. Effect of different concentrations of NaCl used in the extraction of the active component from the papaya seed on the residual turbidity.

the time required for particle destabilization will be greatly reduced, thereby increasing the efficiency of the coagulation process. From the coagulation experiment, extract from the papaya seed has a high potential to reduce the turbidity of Abattoir wastewater even at a low dosage. The result from Fig. 4 showed the highest reduction efficiency of 81.52% was obtained at a dosage of 3 g/L.

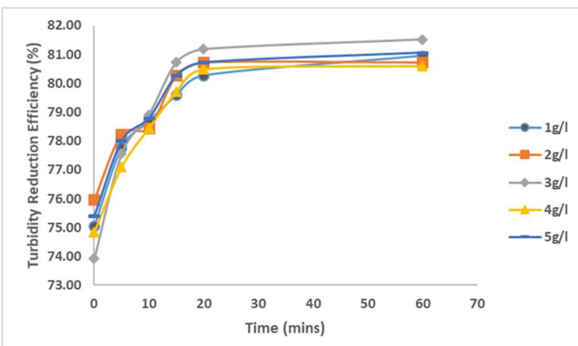

Fig. 4. Effect of varying coagulant dosage on turbidity reduction efficiency

3.5 Effect of pH Variation on Turbidity Reduction Efficiency

Variation of the pH from 2.0 – 10.0, increases the percentage turbidity removal of the coagulant from 82.99% to 86.17% as presented in Fig. 5. One of the disadvantages associated with the use of chemical coagulants is the need for pH adjustment before or after treatment and the need for higher doses of the coagulants (Prakash et al., 2014). From Fig. 5, variation of pH of the wastewater has insignificant effect on the performance of the coagulants extracted from Papaya seed, which can be attributed to the fact that the biomass sample, do not hydrolyse easily in water (Tsamo et al., 2021). Therefore, With the use of coagulant extracted from Papaya seed, there is no need for pH adjustment before or after treatment of the wastewater.

3.6 Effect of Settling Time on Turbidity Reduction Efficiency at Different Temperatures

The effect of settling time on turbidity reduction efficiency was studied at different temperatures of 298, 308, and 318K at pH of 8.0 and PSC dosage of 3 g/L. From Fig. 6, it was observed that the reduction efficiency increased with an increase in settling time, till 20 mins at which equilibrium was attained, with reduction efficiency of 87.41%, 90.02% and 91.38% at 298, 308, and 318K respectively, after which the reduction in turbidity was no longer significant, indicating that most of the colloidal particles settled between 0 – 20 min. A similar result was obtained by Ejimofor (2021) in the coagulation treatment of paint wastewater by Novel Chito-Protein. From Fig. 6, it was also observed that an increase in the temperature, increases the coagulation efficiency as well, which can be attributed to a decrease in viscosity of the ABW with an increase in the temperature and particle kinetic energy (Ejimofor, 2021).

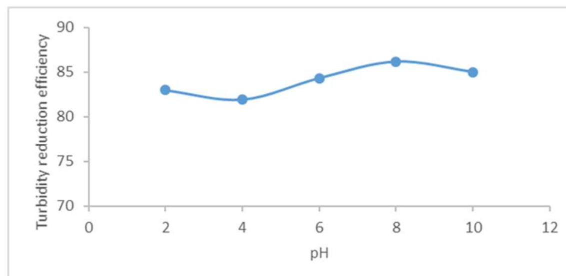

Fig. 5. Effect of varying pH on turbidity reduction efficiency using 3g of PSC

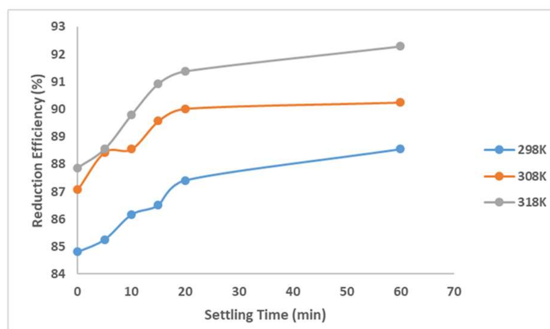

Fig. 6. Effect of varying Temperature of ABW on Turbidity reduction using 3 g/L of PSC and at pH of 8

3.7 Comparison with other Bio-coagulants

When the effectiveness of PSC was compared to that of some other bio-coagulants in reducing the turbidity of some selected effluents, as shown in Table 2, it was discovered that PSC performed comparably at the optimum dosage and time, and that PSC is readily available, easy to handle and does not compete with food stock.

3.8 Coagulation Kinetics Parameters

The coagulation kinetics parameters were determined using the first-order and the second-order reaction rate equations (21 and 23), PSC dosage of 3 g/L, pH of 8, settling

Table 2. Comparison between some Bio-coagulant and PSC in Turbidity Reduction of Wastewater

Effluent	Initial Turbidity (NTU)	Coagulant Type	Optimum Dosage	Optimum Settling Time (min)	Reduction Efficiency (%)	Reference
Abattoir	218.4	De-oiled *Moringa Oleifera*	1.1 mg/L	50.0	95.40	Lagasi et al. (2014)
Batik	1306.0	*Moringa Oleifera*	5000.0 mg/L	180.0	95.50	Effendi et al. (2015)
Slaughterhouse	1065.0	Cotton seed	100.0 mg/L	60.0	43.50	Werberchi et al. (2016)
Abattoir	310.0	Egg shell	1.0 g	40.0	92.00	Okey-Onyesolu et al. (2018)
Aquaculture	404.0	*Sesamum indicum*	0.4 g/L	60.0	82.00	Igwebge and Onukwuli (2019)
Abattoir	310.0	crab shell	3.7 g	46.5	90.95	Okey-Onyesolu et al. (2020)
Abattoir	330.0	Snail shell	1000.0 mg/L	50.0	94.39	Nwabanne and Obi (2019)
Slaughter house	37.3	Rice husk Cypress leaves *Eucalyptus* leaves	5.0 g	60.0	63.54 61.29 45.58	Tsamo et al. (2021)
Abattoir	882.0	*Papaya* seed	0.3 g/L	20.0	91.38	Present study

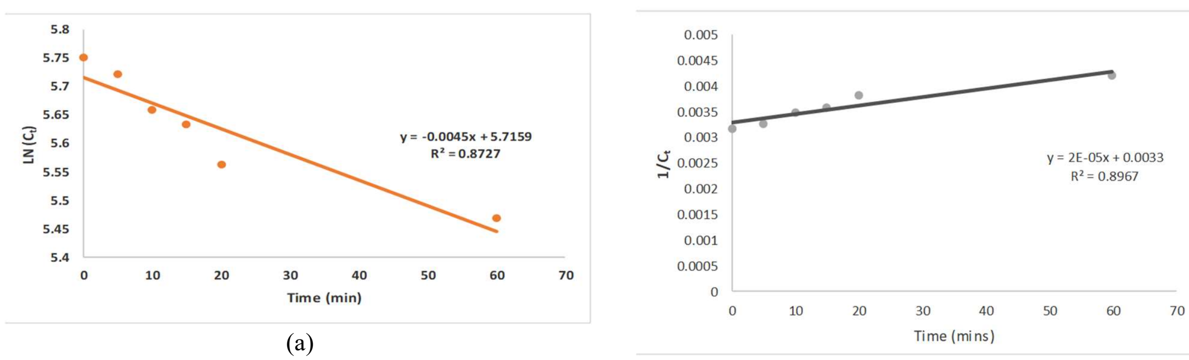

Fig. 7. (a). First-order Kinetics of ABW Coagulation using 3 g/L of PSC, pH of 8 and at 298K. (b). Second-order Kinetics of ABW Coagulation using 3 g of PSC, pH of 8 and at 298K

time of 60 min and temperature of 298 K and presented in Table 3. The coagulation rate constant (K) for the first-order was obtained from the slope of Ln Ct vs time (Fig. 7(a)) while that of the second-order was obtained from the slope of the plot of 1/Ct vs time (Fig. 7(b)), the experimental data fitted best in the second-order than the first-order, from the correlation coefficients presented in Table 3, the high collision efficiency (ε_p) is as a result of the high kinetic energy required to overcome the repulsive forces of the colloidal particles (Menkiti et al., 2011). The Coagulation time of 48.24 min (Table 3) was calculated from Equations 14 and 26, which correspond to the time for the formation of triplet folds of aggregates, while the equilibrium time of 20 min from Fig. 6 corresponds to the time for the formation of doublet aggregates. This implies that an increase in settling time leads to the formation of more folds of aggregates, with 4 folds of aggregates occurring at 72.36 min.

Table 3. Kinetics parameters for coagulation of ABW using PSC

Kinetics Parameter	First-order	Second-order
R^2	0.8734	0.8979
K	0.00450 (min)	0.00002 L/(mg-min)
C_o (mg/L)	303.66	303.03
k_s (L/min)	2.298E-18	2.298E-18
ε_p	1.96E15 min^2/L	8.703E12 1/mg
-r (mg (Lmin/L)	4.05E-3C_t	2E-05C_t^2
T_{ag}	0.2144 L/(mg-min)	48.24 min
t_{max2}	0.1072 L/(mg-min)	24.12 min
t_{max3}	0.2144 L/(mg-min)	48.24 min
t_{max4}	0.3216 L/(mg-min)	72. 36 min

4. CONCLUSION

According to the results of the study, the active component extracted from the Papaya seed using 2 M NaCl effectively reduced the turbidity of the Abattoir wastewater, with an optimum reduction efficiency of 91.38% at pH 8, a dosage of 3 g/L, a temperature of 318K, and a settling time of 20 min. The kinetics of the coagulation process fitted well in the second-order coagulation rate equation with a correlation coefficient of 0.90, rate constant of 0.00002 L/(g. min), collision efficiency of 8.703E12 l/mg and coagulation time of 48.24 min . When compared to previous studies, the coagulant used in this study showed a substantial potential for use as a coagulant for high turbid water and as an alternative to traditional coagulants in the pre-treatment of abattoir wastewater.

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REFERENCES

Antunes, A.D.S., Triques, C.C., Buzanello-Martins, C.V., Mateus, G.A.P., Bergamasco, R. Fagundes-Klen, M.R., 2021. Influence of bionanoparticles to treat a slaughterhouse wastewater. Environmental Technology, 1–17.

AOAC, 1990. Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemist, Washington DC, USA.

APHA, AWWA, WEF, 1999. Standard Method for the Examination of Water and Wastewater. 20th edition Washington, DC, USA: America Public Health Association(APHA), American Water Works Association(AWWA), Water Environment Federation (WEF).

Birima, A., Hammad, H., Desa, M., Muda, Z., 2013. Extraction of natural coagulant from peanut seeds for treatment of turbid water.. IOP Conference Series: Earth and Environmental Science. 16, 1–5.

Bratby, J., 1980. Coagulation and flocculation With an emphasis on water and wastewater treatment. England: uplands press LTD.

Chandran, A., George, D., 2015. Use of papaya seed as a Natural Coagulant for water purification. International Journal of Scientific Engineeering and Research (IJSER), 6, 41–46.

George, D. Chandran, A.J., 2018. Coagulation performance evaluation of papaya seed for purification of river water. International Journal of Latest Technology in Engineering, Management and Applied Science, 7, 50–66

Effendi, H., Sari, R.D., Hasibuan, S., 2015, April. Moringa oleifera as coagulant for batik effluent treatment. In 35th Annual Conference of the International Association for Impact Assessment, Firenze Fiera Congress and Exhibition Center, Florence.

Ejimofor, M., 2021. coagulation treatment of paint wastewaterby novel chito-protein and conversion of post treament sludge to biogas and carbondioxide. s.l.:PhD Thesis (Nnamdi Azikiwe University, Awka)

EWURA, 2014. Water and Wastewater Quality Monitoring Guidelines for Water Utilities, 20. http://extwprlegs1.fao.org/docs/pdf/tan182368.pdf

FAO, 2019. Protecting people and animals from disease threats. Food and Agriculture Organisation of the united Nations. https://www.fao.org/3/i8747en/I8747EN.pdf

Ghebremichael, K. A., Gunaratna, K., Henriksson, H., Brumer, H., Dalhammar, G., 2005. A simple purification and activity assay of the coagulant protein from Moringa Oleifera seed. Water Research, 39, 2338–234.

Gidde, M.R., Bhalerao, A.R., Malusare, C.N., 2012. Comparative study of different forms of moringa oleifera extracts for turbidity removal. International Journal of Engineering Research and Development, 2, 14–21.

Igwegbe, C.A., Onukwuli, O.D., 2019. Removal of total dissolved solids (TDS) from aquaculture wastewater by coagulation-flocculation process using Sesamum indicum extract: effect of operating parameters and coagulation-flocculation kinetics. The Pharmaceutical and Chemical Journal, 6, 32–45.

Kajura, H.M., 1999. The national environment (standards for discharge of effluent into water or on land) regulations. National Environment Act, nema.go.ug/sites/all/themes /nema/docs/effluent_discharge_regulations.pdf.

Kang, J., Trevino, J., 2017. Evaluating moringa oleifera, papaya and pumpkin seed as a natural coagulant. International Journal of Life Sciences research, 5, 126–131.

Khodapanah, N., Ahamad, I., Idris, A., 2013. Potential of using bio-coagulants indigenous to Malaysia for surface water Clarification. Research Journal of Chemistry and Environment, 17, 70–75.

Lagasi, J.E., Agunwamba, J.C., Aho, M., 2014. Comparative studies on the use of ordinary and de-oiled Moringa oleifera in the treatment of abattoir waste water. The International Journal of Engineering and Science, 3, 1–7.

Madhukar V.J., Yogesh S.M., 2014. Assessment of feasibility of natural coagulants in turbidty removal and modeling of coagulantion process. Desalination and Water Treatment, 5812–5821.

Maurya, S., Daverey, A., 2018. Evaluation of Plant - based natural Coagulants for municipal wastewater treatment. 3 Biotech, 8, 77. https://doi.org/10.1007/s13205-018-1103-8

Menkiti, M.C., Igbokwe, P.K., Ugodulunwa, F.X., Onukwuli, O.D., 2008. Rapid coagulation/flocculation kinetics of coal effluents with high organic content using blended and unblended Chitin Derived Coagulants (CSC). Research Journal of Applied Sciences, 3, 317–323.

Menkiti, M.C., Nwoye, C.I., Onyechi, C.A., Onukwili, O.D., 2011. Factorial optimization and kinetics of coal washery effluent coag-flocculation by moringa oleifera seed biomass. Advances in Chemical Engineering and Science, 125–132.

Menkiti, M.C., Okoani, A.O., Ejimofor, M.I., 2018. Adsorptive study of coagulation treatment of paint wastewater using novel brachystegia eurycoma extract. Applied Water science, 8:189.

Menkiti, M.C., Sekeran, G., Ugonabo, V.I., Menkiti, N.U., Onukwuli, O.D., 2016. Factorial optimization and Kinetic studies of Coagulation-flocculation of brewery effluent by crab shell coagulant. Journal of the Chinese Advanced Materials Society, 4:1, 36–61, DOI: 10.1080/22243682.2015.1048287

Menkiti, M.C., Nnaji, P.C., Onukwuli, O.D. 2009. Coag-flocculation kinetics and functional parameters response of periwinkle shell coagulant (PSC) to pH variation in organic rich coal effluent medium. Nature and Science, 7, 1–18.

Nwabanne, J.T., Obi, C.C., 2019. Coagulation-flocculation performance of snail shell biomass in abattoir wastewater treatment. Journal of Chemical Technology & Metallurgy, 54.

Odey, John., 2009. Federal Republic of Nigeria Official Gazette. Short Title; National Environmental (Sanitation and Wastes Control) Regulations 2009. Printed and Published by The Federal Government Printer, Lagos, Nigeria FGP 112/102009/1,000 (0L 54).

Okey-Onyesolu, C.F., Onukwuli, O.D., Okoye, C.C., Ejimofor, M.I. 2018. Deturbidization of abattoir wastewater with extracted egg shell chito-protein via coagulation process. International Conference Proceedings of the Faculty of Engineering. Nnamdi Azikiwe University, Awka, Nigeria, 271–281.

Okey-Onyesolu, C.F., Onukwuli, O.D., Ejimofor, M.I. Okoye, C.C., 2020. Kinetics and mechanistic analysis of particles decontamination from abattoir wastewater (ABW) using novel Fish Bone Chito-protein (FBC). Heliyon, 6, e0446

Okolo, B.I., Nnaji, P.C., Menkiti, M.C., Onukwuli, O.D., 2015. A kinetic investigation of the pulverized okra pod induced coag - flocculation in treatment of paint wastewater. American Journal of Analytical Chemistry, 6, 610–622.

Okuda, T., Baes, A.U., Nishijima, W., Okada, M., 2001. Isolation and characterization of coagulant extracted from moringa Oleifera seed by salt solution. Water Research, 35, 405–410.

Prakash, N.B., Sockan, V., Jayakaran, P., 2014. Wastewater treament by coagulation and flocculation. International Journal of Engineering Science and Innovative technology (IJESIT), 3.

Purss, A., Kay, D., Fewtrell, L., Batram, J., 2002. Estimating the burden of disease from water sanitation and Hygiene at a global level.. Environ Health perspectives, 110, 537–542.

IR Spectrum Table & Chart. 2020. Merck. Retrieved May 11, 2020, from https://www.sigmaaldrich.com/NG/en/technical-documents/technical-article/analytical-chemistry/photometry-and-reflectometry/ir-spectrum-table.

Sonntag, H., Strenge, K., 1987. Coagulation Kinetics and Structure Formation. New York: Springer Science + Business media, LLC.

Tsamo, C., Zama, E.F., Yerima, N.E., Mandela Fuh, A.N., 2021. Comparing the coagulation performance of rice husk, cypress leaves, and Eucalyptus leaves powders with that of alum in improving the turbidity and pH of some local water sources in Bamenda, Cameroon. International Journal of Chemical Engineering, 2021, Article ID 6858936. https://doi.org/10.1155/2021/6858936.

Van-Zanten, J.H., Elimelech, M., 1992. Determination of absolute coagulation rate constants by multiangle light scattering. Journal of Colloid and interface Science, 154, 1–7.

Vishali, S., Karthikeyan, R., 2014. A comparative study of strychnos potatorum and chemical coagulants in the treament of paint industrial effluents: an alternate solution. Separation Science and Technology, 49:16, 2510–2517, DOI: 10.1080/01496395.2014.931098.

Weberich, T., Amaral, A., Schineider, R.M., Bongiovani, M.C., 2016. Coagulation/flocculation of slaughterhouse wastewater using cottonseed as coagulant. Nativa, Sinop, 4, 134–138. DOI: 10.14583/2318-7670.v04n03a03 http://www.ufmt.br/nativa.

WHO, UN-Habitat, 2018. Progress on safe treatment and use of wastewater: piloting the monitoring methodology and initial findings for SDG indicator 6.3.1., Geneva: World Health Organization and UN-Habitat.

Yin, C.Y., 2010. Emerging usage of plant-based coagulants for water and wastewater treatment. Process Biochemistry, 45, 1437–1444.