DOI:10.21276/sjeat.2016.1.4.8

Saudi Journal of Engineering and Technology
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6272 (Print)
ISSN 2415-6264 (Online)

Research Article

Effect of Natural Biomass Treatment on Vegetable Oil Industry Effluent via Coag-Flocculation

Loveth, N. Emembolu[*1], **Chinenye, A. Igwegbe**[2], **Victor, I. Ugonabo**[3]
[123]Department of Chemical Engineering, Nnamdi Azikiwe University, P.M.B.5025, Awka, Anambra State, Nigeria

***Corresponding Author:**
Loveth, N. Emembolu
Email: ln.emembolu@unizik.edu.ng

Abstract: Effect of xanthosoma biomass in vegetable oil industry effluent by coag-flocculation process has been undertaken at room temperature. The coag-flocculation activity and kinetic parameters of xanthosoma biomass in vegetable oil industry effluent were determined at varying; dosages, settling time and pH. The coag-flocculation behaviour of xanthosoma biomass was evaluated using standard Jar test method. The maximum kinetic parameters determined were recorded at K of $3x10^{-5}$L/mg, pH of 6, $t_{1/2}$=33.33 min while the minimum values are recorded at K of 1 $x10^{-5}$, pH of 10, $t_{1/2}$ = 80min. Regression analysis was used to ascertain the accuracy of the fit to the postulated kinetic model. However, it was concluded that the second order kinetic model described the reaction most adequately with highest regression coefficient (R^2) of 0.9869, pH of 6 at 2g dosage. The maximum turbidity removal efficiency (E%) was recorded at 83% for dosage, time and pH indicating that xanthosoma biomass is a potential coagulant for effective wastewater treatment.

Keywords: Xanthosoma biomass, vegetable oil effluent, kinetics, coag-flocculation, variables, effective.

INTRODUCTION

The demand for portable, clean and high quality drinking water is increasing as the non- polluted water sources are decreasing continuously [1, 2]. In order to prevent environmental pollution and infection of drinking water sources, it is imperative that more effective water and wastewater treatment techniques are needed. In developed countries, the waste water is treated before being disposed of in accordance with regulatory standards [3, 4]. Unlike in some developing nations where little or no compliance to the laws governing waste effluent disposal are witnessed.

There are several methods of treating waste water effluents but coag-flocculation is the most preferred due to its cheapness, low operating skill and effective process in treating turbid surface and industrial effluents. As a result of simplicity and cost effectiveness of coagulation flocculation is the commonest wastewater and water treatment in which compounds like ferric chloride or polymer, alum are added to wastewater in order to destabilize the colloidal materials and hence cause the small particles to agglomerate into large settle flocs. Many reports have acknowledged the usage of this process in treatment of industrial effluents produced from dye, textile, refined oil and coagulants are well recognized and undisputed. However, there are some drawbacks associated water the process but it is minimal.

Coagulation – Flocculation Kinetics and Theoretical Principles

The kinetics of coagulation flocculation of vegetable oil effluent using xanthosoma biomass was carried out in accordance with the kinetics of the brownian coagulation as described by [5, 6].

$$\frac{dN_n}{dt} = \frac{1}{2}\sum_{ij} = nK_{ij}N_iN_n - N_n\sum_{i=j}K_{in}N_t \qquad (1)$$

Where the K_{ij} is a second order coagulation rate constant and N_n is the total particle concentration of n-fold clusters. However, for the kinetic of Brownian coagulation of mono-dispersed particles at the early stage is described general by:

$$\frac{dN_t}{dt} = KN_t^{\alpha} \qquad (2)$$

Where k = coagulation rate constant, α = order of coagulation reaction, N_t= concentration of particles (TDSP) at time, t. linearizing equation (2) above gives

$$\ln\left[\frac{dN_t}{dt}\right] = \alpha \ln N_t + \ln K \qquad (3)$$

From equation (3), α and K could be determined. This constant is a product of collision efficiency $\varepsilon_p$and the Smoluchowski rate constant for rapid coagulationK_{Π}.

$$K = \varepsilon_p K_{\Pi} \qquad (4)$$

where ε_p = collision efficiency
K_{Π} = Von Smoluchowski rate constant for rapid coagulation and is given by:

$$K_{\Pi} = 4RD_1 \qquad (5)$$

$$R = 2\alpha \qquad (6)$$

Where α = particle radius, D_1 = particle diffusion coefficient. From Einstein's equation

$$D_1 = \frac{K_B T}{B} \qquad (7)$$

From Stoke's equation,

$$B = 6\pi\eta\alpha \qquad (8)$$

$$\alpha = \frac{R}{2} \qquad (9)$$

Where K_B = Boltzman's constant (molar gas constant per particle); B = friction factor, η = fluid viscosity; T = absolute temperature (K).

Substituting equation (9) into equation (8) gives

$$B = \frac{6\pi\eta R}{2} = 3\pi\eta R \qquad (10)$$

Also, combining equations (10) and (7)

$$D_1 = \frac{K_B T}{3\pi\eta R} \qquad (11)$$

Putting equation (11) into (5), gives

$$K_{\Pi} = \frac{4K_B T}{3\eta} \qquad (12)$$

Again, substituting (12) into (4), produces

$$K = \varepsilon_P \left[\frac{4K_B T}{3\eta}\right] N^{\alpha} \qquad (13)$$

Combining (13) and (2)

$$\frac{dN_t}{dt} = -\varepsilon_p \left[\frac{4K_B T}{3\eta}\right] N^{\alpha} \qquad (14)$$

[7], [8] and [9] report that in real practice, 1≤ $\alpha \leq 2$. Based on this, what is required to evaluate K is to determine the line of better fit between α = 1 and 2, while the experimental data are fitted into linearized form of equation (2).
For α = 2, equation (2) becomes

$$\frac{dN}{dt} = -KN^2 \qquad (15)$$

Integrating equation (15) between limits of N_t and N_0 and t and 0 we arrived at.

$$\int_{N_0}^{N_t} \frac{dN_t}{N_t^2} = -K \int_0^t dt \qquad (16)$$

$$\text{Hence,} \quad \frac{1}{N_t} - \frac{1}{N_0} = Kt \qquad (17)$$

Making N_t the subject,

$$N_t = \frac{N_0}{1 + N_0 K t} \qquad (18)$$

$$N_t = \frac{N_0}{1 + \frac{1}{1/N_0 K}} \qquad (19)$$

$$\text{Let} \quad \tau = \frac{1}{N_0 K} \qquad (20)$$

$$\text{Therefore } N_t = \frac{N_0}{1 + 1/\tau} \qquad (21)$$

When t = τ, equation (21)gives,

$$N_t = \frac{N_0}{2} \qquad (22)$$

Therefore as $N_0 \rightarrow 0.5N_0; \tau \rightarrow \tau_{1/2}$

$$\tau_{1/2} = \frac{1}{0.5 N_0 k} \qquad (23)$$

Turbidity (NTU) can be converted to TSS (mg/L) using equation (24) below,

$$\text{TSS}\left(\frac{mg}{L}\right) = \left(TSS_f\right).T \qquad (24)$$

Where T = Turbidity (NTU); $TSS_{f\,=}$ conversion factor to TSS. In addition evaluation of coagulation- flocculation efficiency is as given below;

$$E\% = \left[\frac{N_0 - N_t}{N_0}\right] \times 100 \qquad (25)$$

MATERIALS AND METHODS

Materials

The materials used for this work were sourced from Anambra State and stored at room temperature. The vegetable oil effluent was stored in dark plastic container to avoid photo-reactions. The refined vegetable oil effluent was characterized according the standard method [7] and the results presented in table 1.

Experimental procedure

The sample of xanthosoma biomass was sourced from Isuaniocha in Awka, Anambra state. The vegetable oil effluent sample was collected from a vegetable oil industry situated in Anambra state and characterized as per standard procedure, shown in table 1. The Jar test experiment was conducted based on standard Bench scale nephelometric method. Appropriate dose of xanthosoma biomass in the range of 1g – 5g was added to 250ml of the effluent. The suspension, tuned to pH range of 2, 4, 6, 8, and 10 by addition of 10M HCL/NaOH was subjected to 5 minutes of vigorous stirring using 688644A Gulenhamp magnetic stirrer (120rpm), then another 30 minutes of settling time. During settling, samples were withdrawn from 2cm depth and changes in TDSP measured for the kinetic analysis (Lab-Tech model 212R Turbidmeter) at varying time intervals of 0, 5, 10, 15, 20, 25, 30 and 60 minutes. The whole experiment was done at room temperature. The data obtained were subsequently fitted into appropriate kinetic models for evaluation of coag-flocculation kinetics and functional parameters.

Table 1: Characterization of Refined Vegetable Oil effluent before and after treatment

Parameters	Units	Before coag- flocculation	After coag- flocculation
Turbidity	NTU	748.00	155.00
Ph	-	5.16	4.62
Conductivity	μ/cm	27.50	5.64
Temperature	^oC	27.00	27.00
TDS	mg/L	905.00	188.00
TSS	mg/L	855.00	176.00
TS	mg/L	1760.00	364.00
Alkalinity	mg/L	586.40	162.00
Dissolved Oxygen	mg/L	12.62	4.83
OIL and Grease	%	43.40	20.10
BODs	mg/L	918.00	190.00
COD	mg/L	1574.00	325.00
Acidity	mg/L	520.31	139.20
Sulphate	mg/L	538.80	194.70
Phosphate	mg/L	1.35	0.53
Total Nitrogen	mg/L	1.82	0.75
Magnesium	Ppm	0.45	0.04
Zinc	Ppm	1.26	0.82
Calcium	Ppm	4.98	4.01
Potassium	Ppm	12.95	10.14
Lead	Ppm	0.12	0.06

Table 2: Proximate analysis of xanthosoma biomass

Parameters	Values %
Ash content	3.60
Moisture content	15.70
Crude fiber	19.50
Fat content	0.40
Crude protein	15.30
Carbohydrate content	44.50

Table 3: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 1g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	1.0	1.0	1.0	1.0	1.0
R^2	0.9649	0.9418	0.9724	0.9432	0.9539
K(L/mg.min)	0.0158	0.0161	0.0160	0.0137	0.0123
N_o (mg/l)	1345.1	1209.7	1251.9	1213.4	1189
$(-rA)$	$0.0158N_t$	$0.0161\ N_t$	$0.0160\ N_t$	$0.0137\ N_t$	$0.0123\ N_t$
$\tau_{1/2}$	43.87	43.053	43.322	50.595	56.353

Table 4: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 2g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	1.0	1.0	1.0	1.0	1.0
R^2	0.9255	0.9364	0.9643	0.9472	0.9539
K(L/mg.min)	0.0156	0.0172	0.0161	0.0139	0.0124
N_o (mg/l)	1240.7	1161.3	1197.4	1258.6	1147.10
$(-rA)$	$0.0156N_t$	$0.0172\ N_t$	$0.0161\ N_t$	$0.0139\ N_t$	$0.0124\ N_t$
$\tau_{1/2}$	44.433	40.299	43.053	49.867	55.899

Table 5: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 3g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	1.0	1.0	1.0	1.0	1.0
R^2	0.9555	0.9699	0.9728	0.9466	0.9383
K(L/mg.min)	0.0162	0.0164	0.0155	0.014	0.0122
N_o (mg/l)	1155.6	1056.3	1106.4	1121.5	1099.7
$(-rA)$	$0.0162N_t$	$0.0164\ N_t$	$0.0155\ N_t$	$0.0140\ N_t$	$0.0122\ N_t$
$\tau_{1/2}$	42.789	42.265	44.719	49.510	56.815

Table 6: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 4g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	1.0	1.0	1.0	1.0	1.0
R^2	0.9555	0.9714	0.9744	0.9693	0.9229
K(L/mg.min)	0.017	0.0162	0.0163	0.0139	0.0131
N_o (mg/l)	1123.7	998	1062.6	1063	1080
$(-rA)$	$0.017N_t$	$0.0162\ N_t$	$0.0163\ N_t$	$0.0139N_t$	$0.0131\ N_t$
$\tau_{1/2}$	40.773	42.787	42.524	49.867	52.912

Table 7: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 5g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	1.0	1.0	1.0	1.0	1.0
R^2	0.9694	0.9606	0.975	0.9641	0.9353
K(L/mg.min)	0.017	0.0169	0.0171	0.0149	0.0133
N_o (mg/l)	1057	951.3	1034	1016	1007
$(-rA)$	$0.017N_t$	$0.0169\ N_t$	$0.0171N_t$	$0.0149N_t$	$0.0133\ N_t$
$\tau_{1/2}$	40.773	41.014	40.535	46.520	52.116

Table 8: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 1g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	2.0	2.0	2.0	2.0	2.0
R^2	0.9765	0.969	0.9828	0.917	0.961
K(L/mg.min)	1E-05	2.1×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	1.0×10^{-5}
N_o (mg/l)	1428.5	1250	1428	1250	1250
$(-rA)$	$0.00001N_t^2$	$0.000021N_t^2$	$0.00002N_t^2$	$0.00002N_t^2$	$0.00001N_t^2$
$\tau_{1/2}$	74+01	40	35	40	80

Table 9: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 2g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	2.0	2.0	2.0	2.0	2.0
R^2	0.9377	0.9691	0.9869	0.9583	0.9581
K(L/mg.min)	1E-05	2.1×10^{-5}	2.0×10^{-3}	3.0×10^{-1}	1.0×10^{-5}
N_o (mg/l)	1250	1252	1250	1251	1250
$(-rA)$	$0.00001N_t^2$	$0.000021N_t^2$	$0.00002N_t^2$	$0.00002N_t^2$	$0.00001\ N_t^2$
$\tau_{1/2}$	8	40	40	40	80

Table 10: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW for varying PH at 3g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	2.0	2.0	2.0	2.0	2.0
R^2	0.9644	0.9749	0.9792	0.9644	0.9428
K(L/mg.min)	2E-05	2.0×10^{-5}	2.0×10^{-3}	2.0×10^{-1}	1.0×10^{-5}
N_o (mg/l)	1111.1	1113.1	1000	1250	1111.11
$(-rA)$	$0.00002N_t^2$	$0.000021N_t^2$	$0.000023N_t^2$	$0.00002N_t^2$	$0.00001\ N_t^2$
$\tau_{1/2}$	30	45	45	40	51

Table 11: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW at varying PH at 4g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	2.0	2.0	2.0	2.0	2.0
R^2	0.9656	0.9745	0.9778	0.9712	0.9272
K(L/mg.min)	2E-05	2.0×10^{-5}	2.2×10^{-3}	2.0×10^{-1}	1.0×10^{-5}
N_o (mg/l)	1000	1111	1111.1	1111.1	1111
$(-rA)$	$0.000018N_t^2$	$0.00002N_t^2$	$0.000021N_t^2$	$0.000019N_t^2$	$0.00001\ N_t^2$
$\tau_{1/2}$	4.5E01	45	45	45	50

Table 12: Coag- flocculation kinetic parameters and regression coefficient of xanthosoma biomass in VOWW at varying PH at 5g dosage

Parameter	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
A	2.0	2.0	2.0	2.0	2.0
R^2	0.9734	0.9646	0.9803	0.9681	0.9424
K(L/mg.min)	2E-05	3.0×10^{-5}	3.1×10^{-3}	2.0×10^{-1}	2.1×10^{-5}
N_o (mg/l)	1110.1	1000	1111	1000	1000.6
$(-rA)$	$0.00002N_t^2$	$0.00003N_t^2$	$0.000031N_t^2$	$0.00002N_t^2$	$0.00002N_t^2$
$\tau_{1/2}$	43	33.33	30	50	50

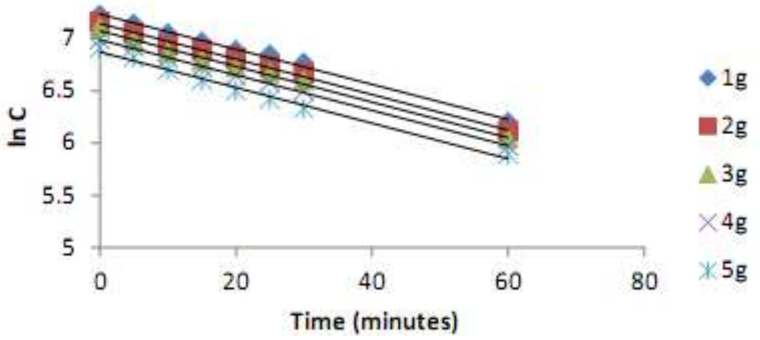

Fig-1: Selected linear plot of lnC vs time at pH = 4

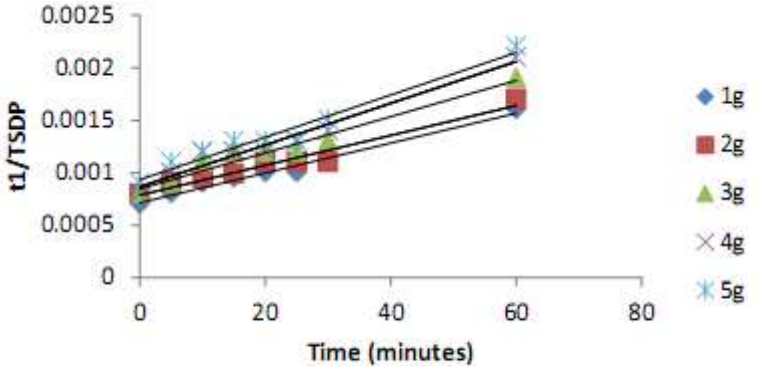

Fig-2: Selected linear plot of 1/TDSP of oil effluent vs time at PH = 4

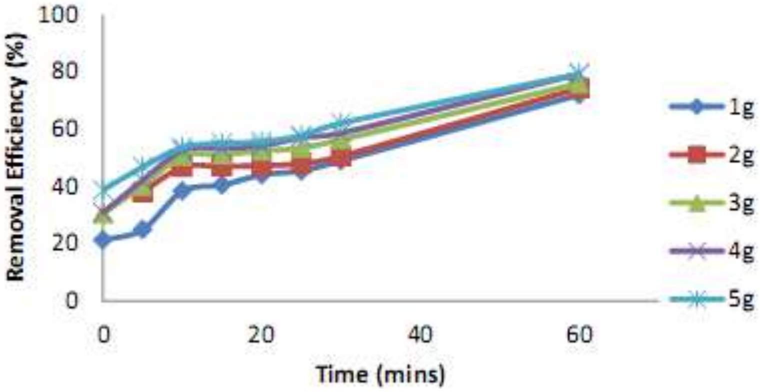

Fig-3: Selected plot of Efficiency vs time at various dosages of coagulant and constant pH

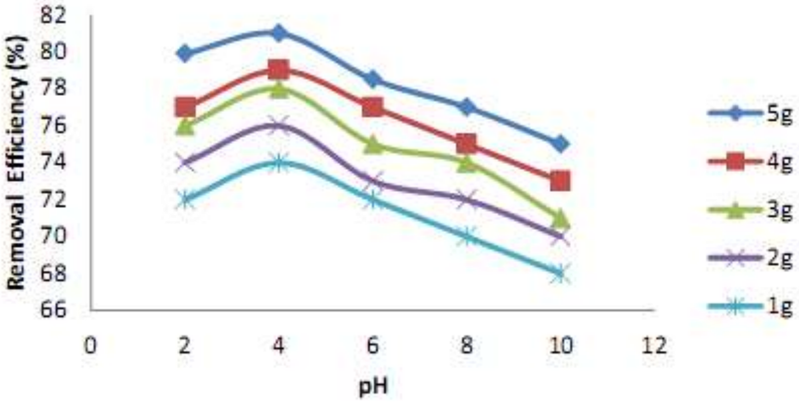

Fig-4: Efficiency vs pH at varying dosages

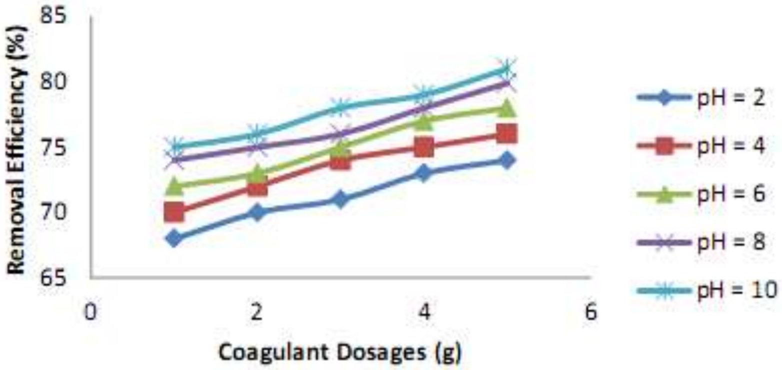

Fig-5: Efficiency vs coagulant dosages

RESULTS AND DISCUSSION

Coagulation-Flocculation Kinetics and regression coefficient parameters

The values of regression coefficient (R^2) parameters obtained from linearized plot of equation 15 termed fig.1. The obtained values are shown in tables 3-12. In general, the values of R^2 shown are more clustered in the neighborhood of pH 2, 4 and 6. Though the highest value of R^2 is achieved at optimum pH=4. This implies that the process of adhesion of TDSP on the coagulant flocs formed during the hydrolysis is governed by monolayer sorption mechanism. Linear regression coefficient was applied to ascertain the level of accuracy of fit the kinetic model expressed as equation 15. The coagulation rate constant K and order of coagulation reaction α were determined from equation (15), designated as the linearized plots shown on figs. 1 and 2. The value of α is evaluated from the slope of the graph and k is determined as the exponential value of the intercept. Hence K is inversely proportional to α and it can be inferred that low α depicts high value of k. This is excepted because k is the rate at which two particles approaches one another [8] and is associated with energy barrier. Tables 3-12 depicts that the optimum of k pH of 4 and 3g dosage.

Plot of efficiency (E%) vs time

The plot of efficiency vs time is shown on fig.3. It depicts the performance of xanthosma biomass coagulant with passage of time at varying pH. The general observable coag-flocculation behaviour shows that turbidity (TSDP) removal efficiency increases with time, for all pH and dosages. The maximum removal efficiency of 83% was recorded at 60 minutes and pH of 10, thereby conforming to the theory of rapid coag-flocculation [6]. At 10-40minutes, the efficiency is between 58% and 72% indicating that at longer time more TSDP are adsorbed on the surface of the coagulant. Therefore the sharp increase in removal efficiency with time is as a result of floc sweep mechanism or combination of bridging-entrapment mechanism [8] and in accordance with [5].

Plot of efficiency vs pH

This is represented in fig. 4. The removal efficiency increases until pH of 4 is attained, further increase in removal efficiency shows remarkable reduction at pH of 6 and beyond for all dosages. This reduction is attributed to the high concentration of hydroxyl ions that will compete with TSDP for adsorption sites. In addition settling of metal hydroxides is inevitable at high pH [13, 14].

Plot of efficiency vs Dosage

The plot of efficiency vs coagulant dosages is depicted on fig. 5. This reveals how changes in coagulant dosages affected coag-flocculation efficiency. The significant feature is that the turbidity (TSDP) removal efficiency as a result of variation in the coagulant dosage did follow a particular trend. However at optimum dosage of 3×10^{-5}L/mg, the system recorded the maximum turbidity removal efficiency of 83%.

Furthermore it can be observed, that the flocs produced by xanthosoma biomass appears vigorous at pH of 10 following the aggregation into large floc, for easy settling and removal [13]. In addition, it is understandable that xanthosoma biomass hydrolyzed in water to give a range of products including cationic complexes which can be adsorbed by negatively charged particles (TSDP) and neutralize their charge. This is one mechanism whereby particles can be destabilized, to encourage flocculation.

CONCLUSION

The effectiveness of xanthosoma biomass in the reduction of total suspended and dissolved particles inherent in vegetable oil effluent has reassured.

REFERENCES

1. Tzoupanos, N. D., & Zouboulis, A. I. (2008). Coagulation–Flocculation process in wastewater treatment: the application of New Generation

Chemical Regents. *International conference on heat transfer thermal Engineering and Environment, Rhodes.*

2. Tasneembano, K., & Virupakshi, A. (2013). Treatment of Tannery wastewater using natural coagulants. *International Journal of Innovative Research for Sciences, Engineering and Technology*, 1-8.
3. **U**gonabo, V. I., Okolo B. I., Nnaji, P. C., Menkiti M. C., & Onukwuli, O. D. (2014). Parametric Response Evaluation for Xanthosoma spp Induced coag- *Flocculation of Brewery Effluent*.
4. Vijayaraghavan, G., Sivakumar, T., & Virnal Kumar, A. (2011). Application of plant based coagulants for wastewater treatment. *International Journal of Advances in Engineering Research and Studies, 1*(1), 88-99.
5. Smoluchowski, M., & Von, (1917). Verucheinermathematischen- Theorie der Koagulations Kinetic Kolloider Lousungen. *International Journal of Research in Physical Chemistry and Chemistry Physics, 92*, 129-178.
6. Ugonabo, V. I., Menkiti, M. C., & Onukwuli, O. D. (2012). Effect of Coag-Flocculation Kinetics on Telfairia Occendentalis seed Coagulant (TOC) in Pharmaceutical Wastewater. *Proceedings of the Faculty of Engineering National Conference on Infrastructural Development and Maintenance in the Nigerian Environment. Nnamdi Azikiwe University, Awka.* 179-190.
7. WST. (2006). About coagulation and flocculation: *Information Bulletin, USA.*
8. Menkiti, M. C., Igbokwe, P. K., & Ugodulunwa. (2008). F.X.O. and Onukwuli, O.D. Rapid Coagulation/Flocculation Kinetics of Coal Effluent with High Organic Content Using Blended and Unblended Chitin Derived Coagulants (CSC). *Research Journal of Applied Sciences, 3*(4), 317-323.
9. Senthil Kumar, M., Gospela Krishna, G. V. T., & Sivasankar, V. (2015). Coagulation performance evaluation of natural and synthetic coagulants in wastewater in Treatment. *ARPN Journal of Engineering and Applied Sciences, 10(*6), 2714-2716.
10. Menkiti, M. C., Onyechi, C. A., & Onukwuli, O. D. (2011). Evaluation of Perikinetics Compliance for the Coag-Flocculation of Brewery Effluent by Brachystegiaeury coma seed Extract. *International Journal of Multidisciplinary Sciences and Engineering, 2*(6), 73-80.
11. Chipasa, K. B. (2001). Limits of Physciochemical Treatment of Wastewater in Vegetable Oil Refining Industry. *Polish Journal of Environmental Studies, 10*(3), 141-147.
12. W.H.O. (2006). Guidelines for the safe use of wastewater, Extract and Greater. Who Health Organization Press, *Geneva, Switzerland, 3.*
13. Stephenson, R. J., & Duff, S. J. B. (1996). Coagulation and precipitation of a mechanical pulping effluent: *Removal of carbon, colour and turbidity, Wat. Res, 30*(4), 781-792.
14. NK, N. N. A., Ahmad, Z. A., Mohammad, H. I., & Mohd, O. A. K, (2001). Chemical Coagulation of settle able solid-free palm oil Mill effluent (POME) for organic Load Reduction. *Journal of Industrial Technology, 10*(1), 55-72.