



## OPTIMIZATION OF COAGULATION EFFICACY OF BANANA STEM JUICE IN WATER TREATMENT

<sup>1</sup>Owoicho, A., <sup>2</sup>Shaibu-Imodagbe, E. M., <sup>1</sup>Sanni, I. M.

<sup>1</sup>Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria-Nigeria

<sup>2</sup>Division of Agricultural Colleges, Ahmadu Bello University, Zaria-Nigeria

\*Corresponding Author's Email: [andrewowoicho24@gmail.com](mailto:andrewowoicho24@gmail.com) Phone Number: 07066667641

### ABSTRACT

This work investigates the optimization of coagulation efficacy of banana stem juice as plant natural coagulant in treatment of raw water. Response Surface Methodology was used to optimize the process using Design Expert Version 10. Factors considered were: coagulant dosage (mg/L), retention time (min), and pH with fifteen experimental runs generated using Box Behnken Design method. The parameters analysed were COD, DO, TSS, TDS and Turbidity. Jar test laboratory scale studies was performed and the result analysed statistically to study the effects of pH, retention time and coagulant dosage on coagulation. The coagulation efficacy was achieved at pH 6.5 with percentage removal of 58.065 % after 60 minutes retention time with dosage of 7.5mL/L. Firstly, before carrying these processes, the raw water sample was characterized to ascertain the initial concentration of the parameters before the jar test. Analysis of variance (ANOVA) was used to evaluate the significance of the model and the variables. The model F-value was 12.06 which implies that the model is significant and that there is only a 0.68% chance that such a Model F-value could occur due to interference. Also, values of "Prob > F" were (0.0062) less than 0.0500 indicating that the model terms are significant. It could be concluded that Banana Stem Juice showed tremendous potential as a bio-coagulant for water treatment purposes and could be applied in the pre-treatment stage prior to secondary treatment.

**Keywords:** Response Surface Methodology, Coagulation, Optimization, Design Expert.

### INTRODUCTION

Coagulation is an essential process in the treatment of both surface water and industrial wastewater which deals with the destabilization of suspended and colloidal particles through addition of coagulants. In conventional water treatment process, chemical based coagulants, namely, alum (AlCl<sub>3</sub>), ferric chloride (FeCl<sub>3</sub>) and polyaluminum chloride (PAC) are used. Basically, aluminium sulphate which is considered as the most and widely chemical coagulant use for water treatment has been reported not suitable due to health and economic consideration (Garde *et al.*, 2017). They are numerous disadvantages associated with usage of these coagulants such as ineffectiveness in low-temperature water, relatively high procurement costs, production of large sludge volumes and the fact that they significantly affect pH of treated water (Subramonian *et al.*, 2015). The adoption of sustainable technology which determined the success of any water treatment plant such as distillation, membrane filtration, reverse osmosis. Carbon adsorption, and ultra-violet radiation are much more expensive than aluminium sulphate as they require sophisticated equipment, high skilled operator, high maintenance and depend on high energy input which in most cases is a very serious challenges most especially in developing countries. It is therefore economically worth wide to investigate other alternative by using natural coagulant derived from plant base compound. A number of researches have shown that, natural coagulants derived from plant base compound on the basis of performance are workable substitute to current chemical as coagulant and flocculants. A preliminary study carried out by Habsal *et al.*, (2013), show that insulin concentration in banana stem juice has high binding capability capable of removing

heavy floc from water during sedimentation process there by reducing the turbidity of the water. Studies on the seed of *moringa olifera* as a natural coagulant has also yield a promising result in water treatment and has been recommended as the best natural coagulant discovered so far that can replace aluminium sulphate (alum), which is used widely for water treatment around the world (Ghebremichael *et al.*, 2005; Bhuptawat *et al.*, 2007, salauwa 2010). These natural coagulant however, have some advantages that have drawn the attention of more environmental researchers such as low cost due to abundant nature of the materials, less health implication, less toxin free, less production of sludge, environmentally friendly and biodegradability. (Subramonian *et al.*, 2015; Ingale and Grandi 2016). Considering the cost and health implication resulting from the use of chemical coagulant in water treatment, it is therefore the use of natural coagulant derived from plant-based compound which is less cost effective could be an alternative to replaced chemical coagulant and in this regards, this research tends to convert banana stem which is discarded all over the world as useless material into useful product by utilizing the juice as natural coagulant in water treatment.

### MATERIALS AND METHOD

#### Sample collection and preparation of Banana stem juice

Matured banana stems (*Musa acuminata*) were collected from Ahmadu Bello University plantation with the thorns removed immediately and the pith of the stem separated from the foliage. 100g of the sliced pieces of the pith (shown in figure I) was mixed with 10ml of distilled water and pounded in a small mortar for easy extraction. This was filtered and the juice collected using a clean white muslin clothe as seen in figure II.

The collected juice was carefully poured into 1litre of white gallon and immediately stored in a refrigerator at 7°C to ensure its freshness and to avoid any fermentation. The coagulation experiment using banana stem juice was carried out the same day.



Figure I: Banana Stem pith used



Plate II: Banana Stem juice

### Collection of water sample

Water sample was collected in a 20 Litre empty jerry can at 6:30am in the morning at the upstream of Ahmadu Bello University dam, main Campus Samaru, Zaria-Nigeria and taken to Water Resources and Environmental Engineering Sanitary Laboratory for analysis.

### Optimization of Coagulation Process of the Raw Water using Banana Stem Juice

Response Surface Methodology (RSM) was used to optimized the process. To determine the effective factors, level and range of the input values for the RSM, preliminary test was conducted using design expert version 10. Three basic factors considered were coagulant dosage, Retention time and pH with the range of values (seen in Table 1) with 15 experimental runs generated using the Box Behnken design as seen in Table 2.0

**Table 1: LEVEL AND RANGE OF INDEPENDENT VARIABLE USED**

Variable	Symbol	Coded Variable levels	
		-1	+1
Dosage	A	5	10
Retention time	B	40	50
pH	C	6.5	8.5

Source: Agunwamba *et al.*, 2016

**Table 2: Experimental runs generated using the Box Behnken design method.**

Number of Runs	Dosage Mg/l	Retention time(min)	pH
Run1	10	60	7.5
Run2	7.5	40	6.5
Run3	7.5	60	6.5
Run4	5	60	7.5
Run5	5	50	8.5
Run6	7.5	50	7.5
Run7	10	40	7.5
Run8	10	50	6.5
Run9	5	50	6.5
Run10	7.5	40	8.5
Run11	7.5	50	7.5
Run12	5	40	7.5
Run13	7.5	60	8.5
Run14	10	50	8.5
Run15	7.5	50	7.5

### Coagulation Jar Test Analysis

Coagulation analysis using jar test was carried out in the Department of Water Resources and Environmental Engineering with a flocculator that comprises four-paddle rotor for 500 mL beakers, with all tests conducted at room temperature. Using a 500 mL graduated cylinder, 300 mL of the raw water to be treated was added to each of the jar test beakers. Each beaker was dosed with increasing amounts of the prepared coagulant (Banana stem juice) according to design Expert specifications and stirred at the “flash mixing” speed of 200 rpm for approximately 5 minutes. The speed of the stirrer was then reduced to 100 rpm, and allowed to stir for 15 min to keep the flocs particles uniformly suspended as seen in Plate III below. The machine was then turned off at the end, and the settling time of 40 min, 50 min and 60 min according to Design Expert was allowed for the flocks to settle, while a portion from the top of each beaker was carefully decanted into a clean flask to determine Turbidity, COD, DO and TSS using the standard method (APHA, 2017).



Plate III: Jar test analysis

### Analytical Analysis

Turbidity test was performed using HACH Model 2100P portable turbid meter with measurement in nephelometric turbidity unit (NTU). The measurement is based on the light-transmitting properties of water. Suspended solid was carried out with the aid of vacuum filtration apparatus. The initial weight of filter paper was recorded after drying in the oven at the temperature of 100°C-105°C for 1hour. A 10ml of the water sample was filtered through a glass fibre filter. The residue was dried at to constant weight at 100°C-105°C for 1hour. The filter paper was then cooled in desiccator before weighing. The total suspended solid content was calculated using the equation 1

$$\text{Total Suspended Solid removal} = \left( \frac{A-B}{C} \times 100 \right) \quad 1$$

where  $A$  is weight of the disk + solids (g),  $B$  is weight of empty filter disk (g),  $C$  is volume of sample (mL).

### RESULTS AND DISCUSSION

Table 3 shows the characterisation results from a free water surface at the upstream side of the embankment of Kubanni Reservoir, Ahmadu Bello University (ABU) Zaria before the coagulation pre-treatment. The treatment was done using the design of experiment as described in section 3.7 and the results presented in Table 4.0 as below;

**Table 3: Characterization result of the turbid water**

Parameters	Turbidity	COD	DO	TDS	TSS
Raw H <sub>2</sub> O readings	570.4	530	170	68.4	700

**Table 4: Compliance of treated raw water using banana stem juice**

Number of Runs	Dosage Mg/l Factor1	Retention time(min) Factor2	pH factor 3	COD	TDS	DO	Turbidity	TSS
Run1	10	60	7.5	440	291.0	75	250.0	10
Run2	7.5	40	6.5	410	254.0	75	273.0	30
Run3	7.5	60	6.5	390	195.4	80	239.2	40
Run4	5	60	7.5	300	196.8	70	255.0	20
Run5	5	50	8.5	360	248.0	75	314.4	100
Run6	7.5	50	7.5	330	251.0	70	293.0	40
Run7	10	40	7.5	300	179.8	65	257.8	20
Run8	10	50	6.5	360	308.0	70	268.2	30
Run9	5	50	6.5	320	230.0	80	268.8	90
Run10	7.5	40	8.5	310	268.0	75	290.0	92
Run11	7.5	50	7.5	310	182.1	55	280.8	370
Run12	5	40	7.5	310	189.0	75	273.4	720
Run13	7.5	60	8.5	310	252.0	75	286.8	670
Run14	10	50	8.5	350	304.0	70	313.2	700
Run15	7.5	50	7.5	330	239.0	75	296.4	240

From the results obtained above, it's pertinent to know that, there was a great improvement in the treated water sample compared to the characterized raw water. There was a reasonable percentage removal efficiency in all the water quality parameters considered above for treatment as evidenced in the characterized results and treated water samples shown in Tables 3 and 4 respectively.

These values were however, much higher compared to the results of Habsah *et al.*, 2013. The differences were due to the sources of water considered for the experiment. While the duo considered waste water treatment for their research using Banana Stem juice, this research focused on the use of Banana stem juice as natural coagulant for raw water treatment.

#### Modelling, Optimization and Statistical Analysis.

Modelling and optimization is of great importance in any process as it improves the yield. The optimization process includes the following step; conducting statistically designed experiments, estimation of the coefficients in a mathematical model, prediction of the response and checking the model adequacy.

Response Surface Methodology (RSM) based on the Box-Behnken design (BBD) was used in modelling and optimizing the factors that influence coagulation process for efficient water treatment with emphasis on turbidity removal. In order to

explore the interaction of the major operating factors on turbidity removal using banana stem juice as plant base compound in the coagulation/flocculation process, three major independent variables considered for use in the Box-Behnken design include dosage of the coagulant (mg/L) retention time (min), and pH as illustrated above in Table 1.0 with their range of values.

#### Responses from Removal Efficiency of water parameters after treatment.

The Box-Behnken statistical design software generated 15 experiments in a randomized order to minimize the effect of uncontrolled variable on response with centre point repeated three times in order to quantify the errors. To optimize coagulation efficacy of the banana stem juice with emphasis on turbidity as the major parameter considered, after generating the experimental runs, the removal efficiency equation was used to calculate the removal efficiency of turbidity and the result presented in Table 5. The experimental runs were carried out based on the conditions given in Tables 1.0 and 2.0 respectively. The targeted responses were detailed for further analysis using statistical methods. The optimization process was established using different response function to assess the performance of the model using the Box-Behnken design (Bezerra *et al.*, 2008).

**Table 5: Box Behnken Design (BBD) Matrix and Design output Response for Optimization of coagulation Efficacy for water treatment**

Run	Factor 1 A: Dosage mL/L	Factor 2 B: Retention Time Min	Factor 3 C: pH -	Response: Removal Efficiency Turbidity %
1	10.0	60	7.5	56.1711
2	7.5	40	6.5	52.1388
<b>3</b>	<b>7.5</b>	<b>60</b>	<b>6.5</b>	<b>58.0645</b>
4	5.0	60	7.5	55.2945
<b>5</b>	<b>5.0</b>	<b>50</b>	<b>8.5</b>	<b>44.8808</b>
6	7.5	50	7.5	48.6325
7	10.0	40	7.5	54.8036
8	10.0	50	6.5	52.9804
9	5.0	50	6.5	52.8752
10	7.5	40	8.5	49.1585
11	7.5	50	7.5	50.7714
12	5.0	40	7.5	52.0687
13	7.5	60	8.5	49.7195
14	10.0	50	8.5	45.0912
15	7.5	50	7.5	48.0365

From the experimental results obtained in Table 5.0 above, the highest turbidity removal efficiency was 58.0645% (at dosage = 7.5, retention time = 60 min, and pH = 6.5), while the least removal efficiency was 44.88% (at dosage = 5, retention time = 50 min, and pH = 8.5). The results obtained were in line with Agunwamba *et al.*, (2016) who also verifies the same range of pH and retention time in their study. From the result, it can be observed that retention time and pH had the most effect on the removal efficiency as the highest removal efficiencies of turbidity and other water parameters were obtained at a retention time of 60 min and a pH range of 6.5-7.5 considered to be slightly acidic/ basic as in the cases of Run 1, Run 3, and Run 4 having removal efficiencies of 56.17 %, 58.06%, and 55.29 % respectively. The range of variation in pH of this work is also in accordance with Habsah *et al.*, (2013), who also reported about the influence of pH for turbidity removal within the range of 6.5-7.5 considered to be slightly acidic/ basic.

#### Identifying Best Response Function for Experimental data

For response variable of turbidity removal, different response function such as, quadratic, fit summary, analysis of variance (ANOVA), model graph for 3D, and contour plots were

generated and correlated with experimental data for regression analysis.

#### Fit Summary Statistics

The fit summary statistics provide important information of summary of calculated statistics and test results for all distributions to fit the model selected. It also analyses the relationship between independent variables and response by regression analysis in order to fit all models to the selected response. From the result presented in Table 6 the fit summary suggests quadratic model with significant terms. *P*-values less than 0.05 which implies that the model is significant, this means that the model has the capacity to give the level of confidence greater than 99.5 %. The quadratic model with *F*-value of 14.98 at  $P \leq 0.0062$  shows that the model is significant. The *p*-value is defined as the probability of receiving a result that is equal or exceed what was actually observed assuming the model produced result that are accurate. The *p*-value less than 0.05 also indicate that the model terms are statistically significant (Tripathi *et al.*, 2009). Table 6 present the fit summary result for turbidity.

**Table 6: Fit Summary for Removal Efficiency**

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Mean vs. Total	769.66	1	769.66			
Linear vs. Mean	0.54	3	0.18	4.05	0.0365	
2FI vs. Linear	0.036	3	0.012	0.22	0.8829	
<b>Quadratic vs 2FI</b>	<b>0.41</b>	<b>3</b>	<b>0.14</b>	<b>14.98</b>	<b>0.0062</b>	<b>Suggested</b>
Cubic vs Quadratic	0.024	3	8.078E-003	0.77	0.6066	Aliased
Residual	0.021	2	0.010			

Total	770.69	15	51.38
-------	--------	----	-------

### Model Selection and Analysis of Variance for turbidity

The interaction between the variables and their responses were analysed using Box Behnken Design (BBD) for Regression and ANOVA analysis in Design Expert version 10 software to develop the best fit equations for the model. The second order polynomial response equation was fitted for turbidity to obtain the model constant. (Raymond *et al.*, 2009).

Model development is dependent on the outcome of analysis of variance which is subjected to confirmation of model adequacy (lack of fit) as evaluated in ANOVA formulation. Analysis of variance was used to evaluate the significance of the model. The ANOVA for removal efficiency with all possible models is shown in Table 7.0. This analysis indicates that model involving all terms are significant and the lack of fit is not significant. when a model displace lack of fit, it means that the presence of unusually large residual occurred from fitting the model or several important terms were excluded from the model (Dharma *et al.*, 2016) and as a result, the model cannot be said to describe the relationship between the independent and the response variables sufficiently. The model F-value of 12.06 implies that the model is significant and that there is only a 0.68% chance

that such a Model F-value could occur due to interference. Also, values of "Prob > F" less than 0.0500 indicates that model terms are significant. In this case, B, C, B<sup>2</sup> are significant model terms having a *p*-value of less than 0.0500. Values greater than 0.100 indicates the model terms are not significant. If there are many insignificant model terms (not counting those required to support the hierarchy), model reduction may be required to improve the model, thus, the non significant terms are removed. The result presented in Table 7.0 show analysis of variance of all complete terms for turbidity efficiency. The model terms A, AB, AC, BC, A<sup>2</sup> and C<sup>2</sup> are the terms not contributing to the hierarchy of the model and thus were removed,. Table 8.0 shows summary regression statistisc of complete terms use for the removal efficiency as a condition for all terms in (Table 7.0) to be adopted for used. The performance indicators considered to access model fitness from table 8.0 include the R<sup>2</sup>. Adjusted R<sup>2</sup>, and predicted R<sup>2</sup>. The model equations are therefore obtained on the basis of the complete and improved model and are presented in Equations (2) and (3) respectively. The equation in terms of coded factors (Equation 2) is used to make predictions by identifying the relative impact of the factors usually by comparing the factor coefficients. The equation in terms of the actual factors (Equation 3) is a predictive model used to recreate the results of this experiment.

**Table 7: Analysis of Variance (ANOVA) for Complete terms**

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
<b>Model</b>	<b>0.98</b>	<b>9</b>	<b>0.11</b>	<b>12.06</b>	<b>0.0068</b>	<b>Significant</b>
<i>A-Dosage</i>	<i>9.025E-003</i>	<i>1</i>	<i>9.025E-003</i>	<i>1.00</i>	<i>0.3633</i>	
<i>B-Retention Time</i>	<i>0.071</i>	<i>1</i>	<i>0.071</i>	<i>7.81</i>	<i>0.0382</i>	
<i>C-Ph</i>	<i>0.46</i>	<i>1</i>	<i>0.46</i>	<i>50.74</i>	<i>0.0008</i>	
<i>AB</i>	<i>4.120E-003</i>	<i>1</i>	<i>4.120E-003</i>	<i>0.46</i>	<i>0.5293</i>	
<i>AC</i>	<i>1.787E-005</i>	<i>1</i>	<i>1.787E-005</i>	<i>1.979E-003</i>	<i>0.9662</i>	
<i>BC</i>	<i>0.032</i>	<i>1</i>	<i>0.032</i>	<i>3.58</i>	<i>0.1172</i>	
<i>A<sup>2</sup></i>	<i>0.019</i>	<i>1</i>	<i>0.019</i>	<i>2.08</i>	<i>0.2085</i>	
<i>B<sup>2</sup></i>	<i>0.35</i>	<i>1</i>	<i>0.35</i>	<i>38.31</i>	<i>0.0016</i>	
<i>C<sup>2</sup></i>	<i>0.030</i>	<i>1</i>	<i>0.030</i>	<i>3.33</i>	<i>0.1277</i>	
Residual	0.045	5	9.027E-003			
<b>Lack of Fit</b>	<b>0.024</b>	<b>3</b>	<b>8.078E-003</b>	<b>0.77</b>	<b>0.6066</b>	<b>not significant</b>
<i>Pure Error</i>	<i>0.021</i>	<i>2</i>	<i>0.010</i>			
Cor Total	1.02	14				

**Table 8: Summary of Regression Statistics of complete terms for Removal Efficiency**

Std. Dev.	0.095	<b>R-Squared</b>	<b>0.9560</b>
Mean	7.16	Adj. R-Squared	0.8767
C.V. %	1.33	Pred R-Squared	0.5757
PRESS	0.43	Adeq Precision	12.022
-2 Log Likelihood	-44.52	BIC	-17.44
		AICc	30.48

$$E_R = +23.956 - 0.10002A - 0.21964B + 1.55673C - 1.28373 \times 10^{-3}AB + 8.45379 \times 10^{-4}AC - 8.98475 \times 10^{-3}BC + 0.0114201A^2 + 3.06038 \times 10^{-3}B^2 - 0.090207C^2 \quad (2)$$

where:

A – Dosage (mg/L)

B – Retention time (min)

C - pH

Table 9.0 provide the regression statistics used to access the quality of the model in Table 7.0. The performance indicators used to access the fitness of this model are  $R^2$ , Adjusted  $R^2$  and Predicted  $R^2$ . The  $R^2$  gives the percentage of variation explained by the effective independent variables; it is a reflection of the variability of the dependent variable which can be explained by its relationship with the independent process variables (Dharma *et al.*, 2016). It can be observed in Table 9.0 that the value of  $R^2$  is close to unity (0.9560) showing close agreement between predicted and experimental responses (Onoji *et al.*, 2016). The  $R^2$  value of 0.9560 means that the variation of 95.60% dependent variables was attributed to the independent factors and only 4.4% could not be explained by the model. The high value shows that the model is statistically significant. For a model to be statistically adopted for use according to (Montgomery 2009 and Odili *et al.*, 2020),  $R^2$  should be at least 0.8 and from the result provided, the  $R^2$  was 0.9560 which shows that the model was ok. The condition for adopting a model according to the same authors also talks about the predicted and the adjusted  $R^2$  which state that for a model to be adopted for use, the differences between the adjusted  $R^2$  and predicted  $R^2$  should not be more than 0.2 and when it was confirmed from the result presented in Table 9.0 the value was more than 0.2, thus the condition for adopting this model was not met which entails that the equation 2 generated for this model cannot be adopted for used. In this case, the model was improved by removing all the necessary terms not contributing to the hierarchy of the model development and Table 9.0 provided the improve terms for the new model. Table 10 shows summary regression of statistical of improved terms for Removal Efficiency used to access the fitness of the model in Table 9.0

**Table 9: Analysis of Variance for the developed model. (Adjusted  $E_R$  model)**

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
<b>Model</b>	<b>179.81</b>	<b>3</b>	<b>59.94</b>	<b>22.50</b>	<b>&lt; 0.0001</b>	<b>Significant</b>
<i>B-Retention Time</i>	15.35	1	15.35	5.76	0.0352	
<i>C-Ph</i>	92.54	1	92.54	34.74	0.0001	
$B^2$	71.92	1	71.92	27.00	0.0003	
Residual	29.30	11	2.66			
<b>Lack of Fit</b>	<b>25.16</b>	<b>9</b>	<b>2.80</b>	<b>1.35</b>	<b>0.4958</b>	<b>not significant</b>
<i>Pure Error</i>	4.14	2	2.07			
Cor Total	209.11	14				

**Table 10: Summary of Regression Statistics of complete terms for Removal Efficiency**

Std. Dev.	1.63	R-Squared	0.8599
Mean	51.38	Adj. R-Squared	0.8217
C.V. %	3.18	Pred R-Squared	0.7060
PRESS	61.48	Adeq Precision	14.922
-2 Log Likelihood	52.61	BIC	63.44
		AICc	64.61

The model developed for the improved terms is presented in Equations 3

$$+23.956 - 0.21964B + 1.55673C + 3.06038 \times 10^{-3}B^2 \quad (3)$$

where:

B – Retention time (min)

C – pH

Table 9.0 shows the analysis of variance (ANOVA) for the develop model and table 10 shows summary regression statistics of the improved terms use for the removal efficiency as a condition for all terms in (Table 9.0) to be adopted for use. From the result presented in table 9.0, The model F-value of 22.50 implies that the model is significant and that there is only 0.01 % chance that a model F-value could occur due to interference. Values of "Prob > F" less than 0.0500 indicates that model terms are significant. In this case, C, BC, and C<sup>2</sup> are significant model terms. The "Lack of Fit F-value" of 1.35 implies that there is a 49.58 % chance that a "Lack of Fit F-value" this large could occur. Proceeding to confirm the adequacy of the model presented in Table 9.0, the performance indicators R<sup>2</sup>, Adjusted R<sup>2</sup> and predicted R<sup>2</sup> in Table 10 were accessed. In this case, the condition for a model to be adopted for use were met as the differences between the adjusted R<sup>2</sup> and predicted R<sup>2</sup> was 0.1157 which is less than 0.2 and R<sup>2</sup> was 0.8599 thus satisfying the conditions of (Montgomery 2009 and Odili *et al.*, 2020). Data spread over the fitted model is signified by the lack of fit. The insignificant lack of fit as shown in Table 9 implies that the removal efficiency model fit adequately to the data. The equation in terms of coded factors (Equation 2) is used to make predictions by identifying the relative impact of the factors usually by comparing the factor coefficients. The equation in terms of the actual factors (Equation 3) is a predictive model used to recreate the results of this experiment. It shows the combination of second order polynomials formed by combining the input variables that provide the output.

#### Model Graph for Removal Efficiency

The model graph for removal efficiency presents the contour maps and 3D rendering of the predicted response as a function of the experimental process parameter factors. It explains the effects of changing each factor while holding others constant. A steep slope in a factor shows that the removal efficiency is sensitive to the factor while a relatively flat line shows insensitivity to change in that particular factor.

#### Surface and Contour Plots

The 3-D response surface plots and the corresponding 2-D contour maps generated by the model for removal efficiency are shown in Figures 1.0 to 4.0. The plots give the removal efficiency trend with simultaneous changes in the significant factors. Since factors A, B and C are significant for the removal efficiency, the perturbation plot in Figure 4.0 was used to set priority on the model graph. A steep slope or curvature in a factor indicates that the response is sensitive to that factor. A relatively flat line indicates insensitivity to change in that particular factor. These influential factors are good choices for the axes on the contour plots. From the plot, factors B and C are observed to have a steep slope or curvature which indicates that the factors are sensitive and have more impact on the outcome of removal efficiency.

It is also observed that an increase in both factor B leads to an increase in removal efficiency to a certain point after which there was a decrease in retention time with a reasonable increase in the removal efficiency, similarly, factor C decreases as the removal efficiency increases to a certain level within the experimental value range. However, an optimum level is attained after which removal efficiency starts to increase with a further decrease in both factors. This is also observed as shown in Figures 1 to 3 respectively. Figure 1 (a) and (b) presents a contour plot and a 3-D surface plot showing an interaction between retention time in min and dosage on the removal efficiency of water parameters after treatment with the pH kept constant, this plot indicates that both retention time in min had a positive impact on the optimization process with little or no impact noticed on dosage

As the retention time increased, a corresponding increase in removal efficiency was observed. Figure 2.0 (a) and (b) also presents a contour plot and a 3-D surface plot showing an interaction between pH and dosage (mL/L) on the removal efficiency when retention time was kept constant, this plot indicates that the interaction between both parameters had a little effect on the removal efficiency, nevertheless, as the pH decreased, the removal efficiency increased. Figure 3.0 (a) and (b) also confirms the sensitivity of retention time and pH on removal efficiency.

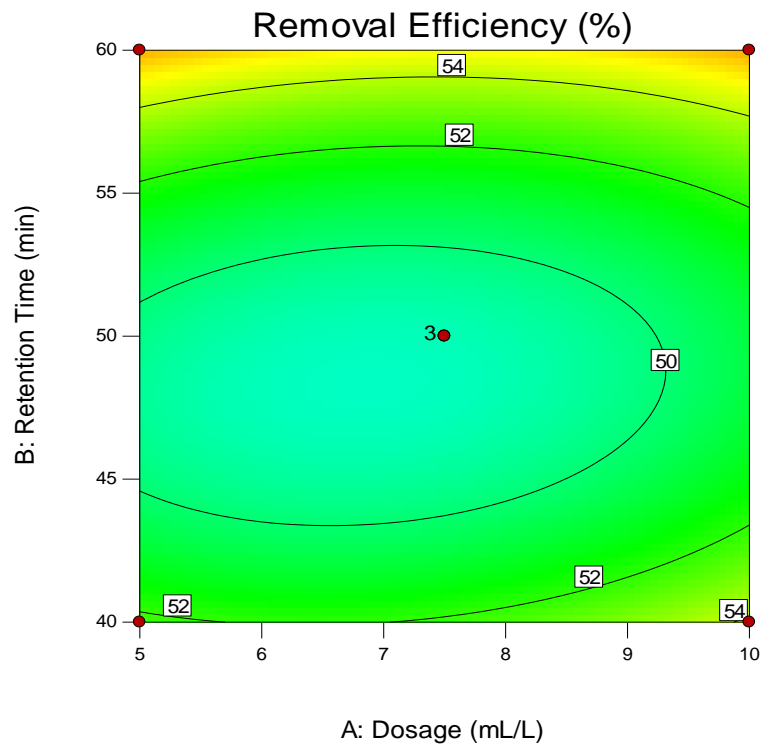


Design-Expert® Software  
 Factor Coding: Actual  
 Turbidity (%)

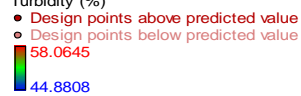


X1 = A: Dosage  
 X2 = B: Retention Time

Actual Factor  
 C: pH = 7.5



Design-Expert® Software  
 Factor Coding: Actual  
 Turbidity (%)



X1 = A: Dosage  
 X2 = B: Retention Time

Actual Factor  
 C: pH = 7.5

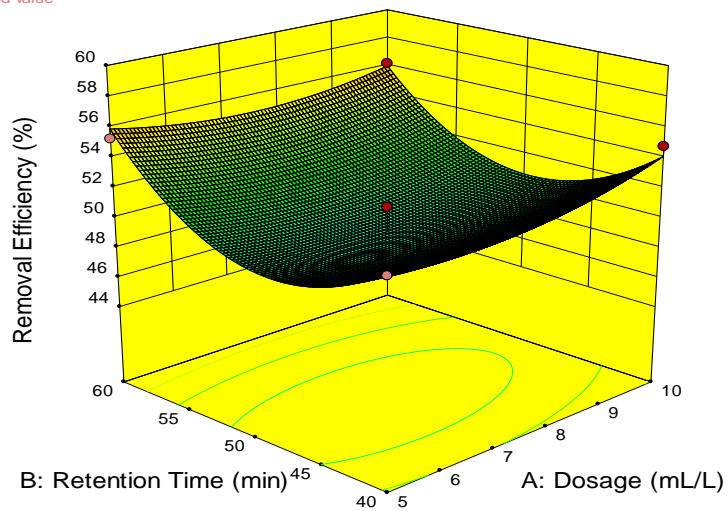
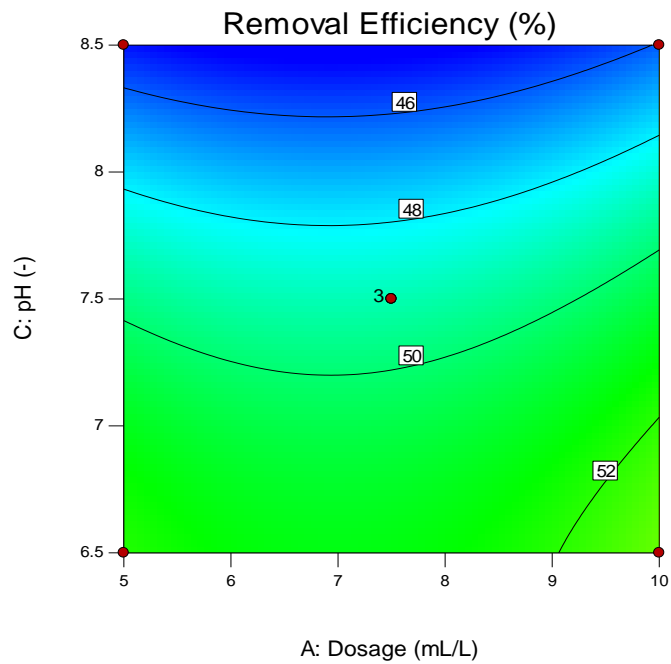


Figure 1: 3-D surface and contour plots of removal efficiency with retention time and dosage. (a) contour map (b) surface plot.

Design-Expert® Software  
 Factor Coding: Actual  
 Turbidity (%)  
 ● Design Points  
 58.0645  
 44.8808  
 X1 = A: Dosage  
 X2 = C: pH  
 Actual Factor  
 B: Retention Time = 50



Design-Expert® Software  
 Factor Coding: Actual  
 Turbidity (%)  
 ● Design points above predicted value  
 ● Design points below predicted value  
 58.0645  
 44.8808  
 X1 = A: Dosage  
 X2 = C: pH  
 Actual Factor  
 B: Retention Time = 50

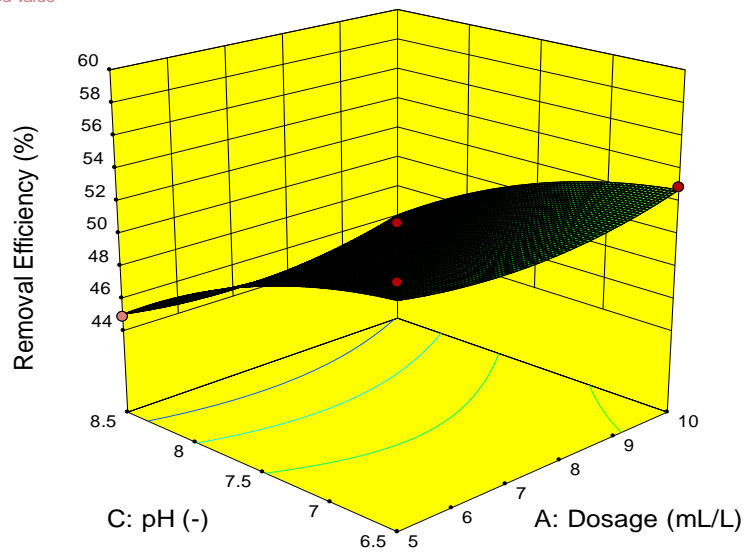


Figure 2: 3-D surface and contour plots of removal efficiency with pH and Dosage. (a) contour map (b) surface plot.

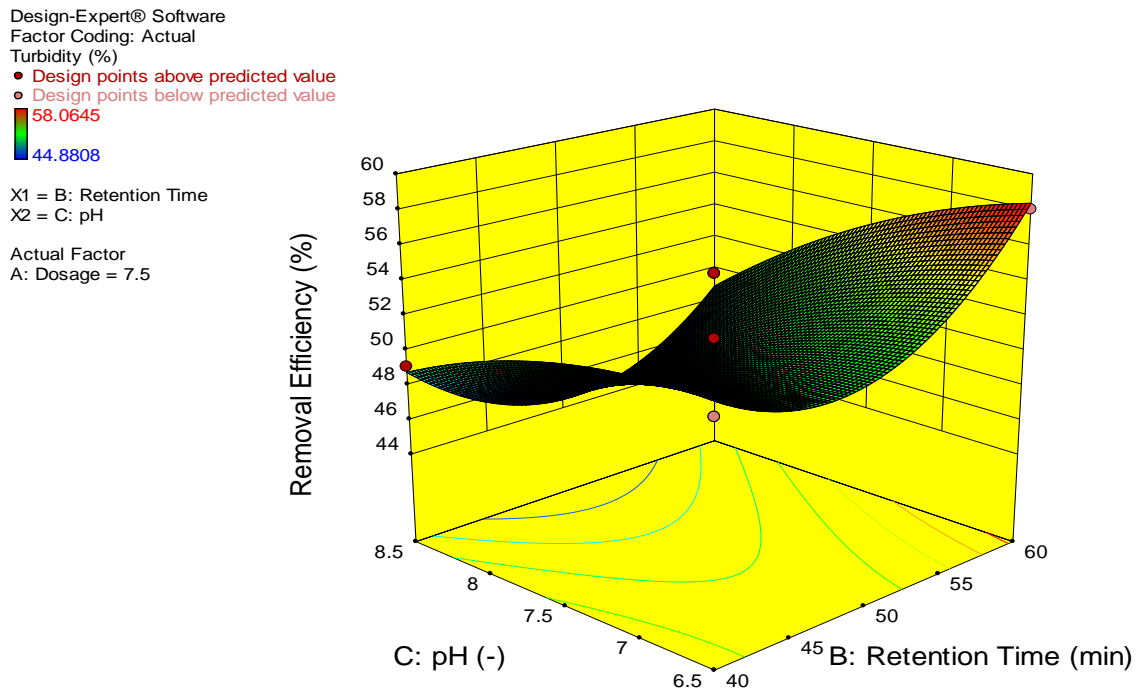


Figure 3: 3-D surface and contour plots of removal efficiency with pH and retention time. (a) contour map (b) surface plot.

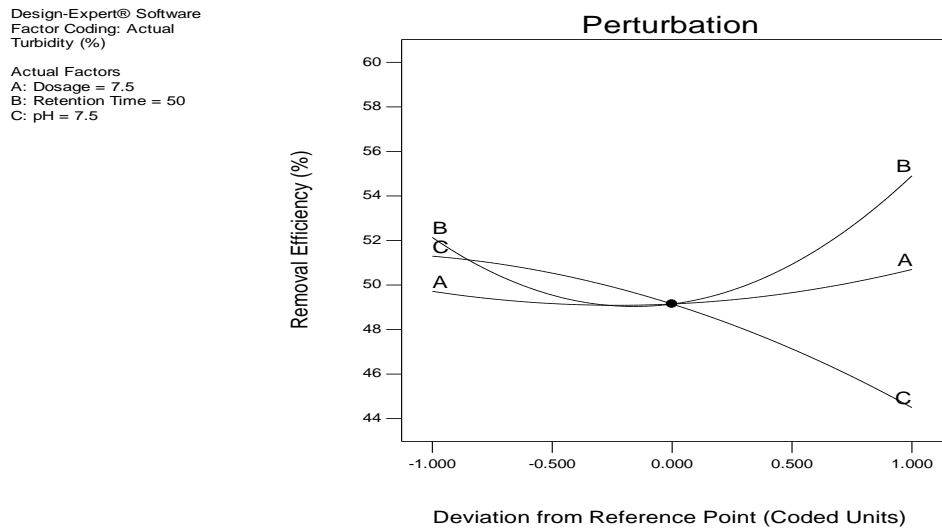


Figure 4: Perturbation plot for Removal Efficiency.

## CONCLUSION

Base on the results presented in this work, the following conclusions can be drawn;

1. Banana Stem Juice is an effective natural coagulant which can be used in water treatment in its crude form.
2. There is a reasonable amount of percentage removal efficiency (58.065 %) found in water treatment using Banana stem juice. The effects of Dosage, Retention time and pH on water treatment efficacy were investigated using RSM.
3. Results from the analysis of variance indicated a significant difference ( $p < 0.05$ ) within and between the final measurements for optimization. The optimum conditions for the factors investigated were at a Dosage of 7.5mL/L, Retention time of 60 min and pH of 6.5 with an optimum treatment efficiency of 58.065%. Generally, the percentage treatment efficiency of the selected water parameters (TSS, Turbidity, TDS, COD, and DO) using banana stem juice showed tremendous potential as a plant-based natural coagulant in water treatment.
4. Banana stem juice contains polysaccharide compounds inulin (1.22016mg/mL), which is a natural polymer for bridging and entrapping the microfloc to form larger floc (Habsah *et al.*, 2013). Therefore, this will help in fast settlement of the floc for coagulation of turbid water. It is suggested that banana stem juice is to be used in the pre-treatment stage of water treatment before the secondary treatment.

## REFERENCES

- Agunwamba, J. C, Aho, M. I, Iorwua M. B, and Tiza, M. T. 2016. Response Surface Optimization of Treated Turbid Water Using Banana Stem Juice. *International Journal for Innovative Research in Multidisciplinary Field* Issn – 2455-0620 Volume - 2, Issue - 8, Aug – 2016
- Bezerra, M.A.; Santelli, R.E.; Oliveira, E.P.; Villar, L.S.; Escalera, L.A. Response surface methodology (RSM) as a tool for optimization in analytical chemistry. *Talanta* 2008, 76, 965–977.
- Bhuptawat, H., Folkard, G.K., Chaudhari, S. (2007). Laboratory evaluation of a water-treatment sequence using Moringa oleifera seed coagulant. *Int. J. Water* 3(3): 299-315
- Dharma S., Masjuki H.H., Ong H.C., Sebayang A.H., Silitonga A.S., Kusumo F., Mahlia T.M.I (2016). Optimization of biodiesel production process for mixed jatropha curcas ceiba pentandra biodiesel using response surface methodology. *Energy conversion and management*, volume 115, 178-190

Garde, W. K., Buchberger, S. G., Wendell, D., & Kupferle, M. J. (2017). Application of Moringa Oleifera seed extract to treat coffee fermentation wastewater. *Journal of Hazardous Materials*, 329, 102–109

Ghebremichael, K.A., Gunaratna, K.R., Hongbin, H., Brumer, H., Dalhammar, G., (2005). A simple purification and activity assay of the coagulant protein from Moringa oleifera seed. *Water Res.* 39(11): 23338-2344

Habsah Alwi, Juferi Idris, Mohibah Musa, and Ku Halim Ku Hamid (2013). A Preliminary Study of Banana Stem Juice as a Plant-Based Coagulant for Treatment of Spent Coolant Wastewater. Hindawi Publishing Corporation, *Journal of Chemistry* Volume 2013, Article ID 165057, 7 pages <http://dx.doi.org/10.1155/2013/165057>

Ingale, SP. and Gandhi, FP. 2016. Effect of aqueous extract of Moringa oleifera leaves on pharmacological models of epilepsy and anxiety in mice. *International Journal of Epilepsy*. DOI: 10.1016/j.ijep.2016.02.001

Odili, U. C., Ibrahim, F. B., Shaibu-Imodagbe, E. M. and Atta, H. I. (2020). Optimization of Crude Oil Biodegradation of Fungi Isolated from Refinery Effluent Site using Response Surface Methodology. *NIGERIAN JOURNAL OF TECHNOLOGICAL DEVELOPMENT*, VOL 17, NO. 4, DECEMBER 2020.

Raymond, H. Myers, Douglas C. Montgomery, and Christine M. Anderson- Cook (2009). *Response Surface Methodology: process and product Optimization Using Designed Experiments*, Wiley; 3<sup>rd</sup> Edition.

Samuel Erhigare Onoji, Sunny E Iyuke, Anselm I. Igbafe and Michael O. Daramola (2016). Hevea brasiliensis (rubber seed) oil: modelling and optimization of extraction process parameters using response surface methodology and artificial neural network techniques, *Biofuels*, 10:6, 677-691, DOI: 10.1080/17597269.2017.13381222

Saulawa Badruddeen Sani (2010). *Stabililty studies of Moringa Oleifera Seed Aqueous Extract for Use in Water Treatment in Rural Areas*. Unpublished MSc thesis Submitted to the department of Water Resources and Environmental Engineering, Ahmadu Bello University Zaria-Nigeria

Tripathi, P.; Srivastava, V.C.; Kumar, A. Optimization of an azo dye batch adsorption parameters using Box-Behnken design. *Desalination* 2009, 249, 1273–1279.

American Public Health Association (APHA), *Standard Methods* 2017



©2021 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via <https://creativecommons.org/licenses/by/4.0/> which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.