International Journal of Information, Engineering & Technology
Volume 12, Issue 10, PP 116-127, ISSN: 2360-9194, February, 2025
OTL: 4272-1454-381-12108-1
Double Blind Peer Reviewed International Research Journal
Journal Series: Global Academic Research Consortium (garc)
arcnjournals@gmail.com
https://arcnjournals.org

Optimization of Turbidity Removal from Surface Water with *Moringa Oleifera* and Soya Beans Pods Extracts Using Response Surface Methodology (RSM)

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Drawbacks associated with chemical coagulants is given attention to the use of plant based-coagulants. The pods of moringa and soya beans- an ecofriendly, economical and futuristic was evaluated for high turbid water treatment. Design of experiment was carried out using response surface methodology. Investigations were conducted using prepared turbid water with initial turbidity of 300NTU with coagulant dose (8 to10mg/l), contact time (15 to 25 secs) and mixing speeds (50 to 150rpm). Results revealed that soya beans pod yielded high turbidity of 91% at 8mg/l does, contact time of 20secs and mixing speed of 100rpm. Moringa pod gave turbidity removal of 84.47% at a coagulant dose of 10mg/l, contact time of 20 secs and mixing speed of 100rpm. The characterization of the pods of moringa and soya beans using Fourier transform infrared (FTIR) spectroscopy, scanning electron microscope (SEM) and Energy-dispersive X-ray (EDX) technique revealed that the presence of protein and carbohydrates causes its coagulating ability and thus affirms that the mechanism of coagulation for plant based coagulants is adsorption and neutralization of charges. A cost comparison with alum indicated that moringa oleifera pod and soya beans pod are 31.31% and 99.19% cost effective compare to alum.

Keywords: *Coagulation, Chemical, Optimization, Treatment, Turbidity*

1.0 Introduction

Turbidity removal is an integral part of water treatment in order to attain clean and palatable water quality. The use of chemicals such as alum and chlorine for turbidity removal and disinfection is amust in the conventional approach to water treatment. It's no longer news that the use of these chemicals are harmful to both human health and environment. Chlorine have been found to be carcinogenic via its by products such as trihalomethanes, halo acetone are few of its disinfection by products. Several research had also linked Alzheimer disease to residual alum (Walton, 2013). As a result of these negative effect on man and its environs, it is essential to explore the use of natural available plants as an alternative to the convectional chemicals. With increasing awareness on the use of plant in water treatment, Government and other stakeholders need sustainable alternatives that is affordable and accessible.

Moringa oleifera is one of the most common plant found in many countries. Although it originated from the sub- Himalayan northwest of India, Afghanistan, Pakistan and Bangladesh. It is also found in African countries such as Nigeria and other regions like south east Asia, south America and Caribbean Island (Bichi, 2013). It is a multipurpose tree due to various uses such as, food, medicine, coagulant and contain oil commonly known as Ben oil. The seed and leaves of moringa have been used for water treatment in terms of turbidity removal or disinfection. A comparison analysis of moringa oleifera coagulant with the conventional chemicals indicated that moringa oleifera coagulant is more advantageous in terms of cost effectiveness, no effect on pH, less sludge production and little effect on the environment.

Among other plants used as coagulant, which was also evaluated for the purpose of these work is the soya beans. much have not been said on its potentials. It is rich and contain about 43% protein (Saha et al, 2008). It also contains oil and carbohydrate of about 20% and 35% respectively (Liu, 2012). Other uses of soya beans include its coagulative ability which aid in turbidity removal in water treatment. It was opined that soya beans consist of active coagulating aids which most plant have been reported to have. the cost effectiveness of soya beans and moringa was a factor of consideration since it's in expensive when compare to the convectional chemicals. The pods of these plants was an option due to the fact that it has little or no economic value. The pod of moringa is more or less a waste since it does not taste palatable even to animals. While that of soya beans may serve as animal feed but may have an alternative and the whole of both plant and animal is for man to feed on them for survival. Furthermore, the efficiencies of the coagulation abilities in this study was optimize.

2.0 Material and Methods

2.1 Preparation of Turbid Water

Materials required – Kaolin, beaker (1L), magnetic stirrer (model-gallenhama) and tap water.

Synthetic turbid water 300 NTU for the jar tests was prepared by adding kaolin to tap water in a beaker containing 1L of tap water and about 30 g of the kaolin was added to it. The suspension was stirred using a magnetic stirrer (model-gallenhama) for about 1 hour so as to obtain a uniform dispersion of clay particles. It was allowed to settled for at least 24 hours for complete hydration of the clay materials. The supernatant suspension of synthetic turbid water was added to the sample water to achieve the desired turbidity (Gidde et al.2012, Abubakar & Kasim 2018).

2.2 Preparation of Stock Solution from moringa oleifera and soya beans pods.

For the purpose of this work, different coagulant was prepared from the natural plant – Glycine Max L (Soya beans) pod and Moringa oleifera pod.

An 10g of Moringa pod and soya pod each was separately dissolve in beakers which contain 100 ml of distilled water and magnetic stirrer was used to stir for 10 min in order to release the active ingredient. This suspension was filter twice using a muslin cloth and a filter Whatman (no 1) paper. This is the stock solution that was used for the experiment. Fresh solution of the coagulant was prepared daily to prevent aging (Muyibi and Evinson, 1995).

2.3 Design of Coagulation Experiments

Design expert software version 10.0 (stat-Ease, inc). was employed for design of experiments (DOE), using response surface method (RSM). The treatment variables selected for this study were coagulant dose (ranging from 8 to 12 g), contact time (varying from 15 to 25secs) and mixing speed (ranging from 50 to 150 rpm). Turbidity removal efficiency (%) was set as response of treatment. The design summary and the out of the 20 experiment were given in table 2 for central composite design. The experiment was repeated three times and the average was observed as the response.

2.4 Jar Assay

The jar test apparatus (model- Edibon) has six beakers of 1000ml of the raw water sample of same turbidity and different dose of coagulants (8 and 10ml) was applied to the beakers using pipette separately. The water samples were agitated simultaneously at different rotational speed. The speed of the flocculation and time was adjusted and started at a low speed of 50rpm for 30 min and high speed of 125 rpm for 4 min and in order to reproduce different mixing intensities which yield flocculation process for pilot test (Emest et al., 2017). The contact time was observed and note. The apparatus was stopped and allow to settle for 60 minutes - settling time (Aziz et al., 2019). After the settling time, the sample was withdrawn using pipette from the supernatant and the residual turbidity was measure also the efficiencies of the high and medium turbid waters was determined. All tests were performed in triplicate for reliable and valid results. Turbidity removal efficiency was calculated using the equation below

$$Turbidity\ Removal\ Efficiency\ (\%) = \frac{C_i - C_f}{C_i} \times 100$$

Where C_i is the initial turbidity of the raw water sample

C_f is the final turbidity of the raw water sample.

3.0 Results and Discussion

3.1 Turbidity Removal by Coagulants

Turbidity removal by moringa varies from 70.33 to 84.47 with average removal of 78.85% for Moringa oleifera pod, while soya beans achieved a better removal with values varying between 84.00 % to 91.00 % and average of 87.49%. the details of the 20 runs of experiment is given in Tables 3.1 and 3.2 for both moringa and soya beans respectively. The highest turbidity removal was achieved at a dose of 10mg/l, contact time of 20secs and mixing speed of 100rpm.

Table 3.1: Experimental design and results obtained from optimization for moringa oleifera pod

Run	Factor 1 A:Amount of coagulant mg/L	Factor 2 B:Contact time Secs	Factor 3 C:Mixing speed RPS	Response 1 Removal efficiency %
1	12	15	50	73.60
2	8	20	100	81.20
3	8	15	150	70.33
4	10	25	100	80.27
5	12	15	150	75.49
6	10	20	100	81.02
7	12	20	100	79.20
8	12	25	150	75.80
9	10	20	150	78.00
10	10	20	100	80.93
11	10	20	50	77.47
12	8	25	50	77.93
13	10	15	100	77.80
14	10	20	100	79.73
15	10	20	100	81.07
16	12	25	50	79.40
17	10	20	100	84.47
18	8	25	150	79.87
19	10	20	100	80.87
20	8	15	50	82.53

Table 3.2: Experimental design and results obtained from optimization for soya beans pod.

Run	Factor 1 A:Amount of coagulant g/L	Factor 2 B:Contact time Secs	Factor 3 C:Mixing speed RPM	Response 1 Removal efficiency %
1	10	20	100	89.00
2	8	25	50	84.00
3	10	20	100	89.20
4	8	15	150	90.20
5	12	25	150	88.00
6	12	25	50	83.73
7	12	15	150	84.00
8	10	20	150	87.40
9	10	20	100	89.04
10	12	20	100	89.13
11	10	20	50	84.40
12	10	20	100	88.00
13	10	20	100	89.50
14	8	25	150	87.60
15	10	25	100	86.67
16	8	20	100	91.00
17	10	15	100	88.13
18	12	15	50	84.40
19	10	20	100	89.13
20	8	15	50	87.25

3.2 Optimization of operating parameters in surface water treatment

Table 3.1 shows the experimental design and the result of the turbidity removal when it is under the effect of dosage of coagulant, contact time and mixing speed. The outcome gave optimum conditions at dosage, contact time and mixing speed as 8.67mg/l, 24.07min and 136.47rpm respectively. Under these conditions the predicted turbidity removal was 80.35% and 88.30% for moringa and soya beans respectively.

Also, the quadratic and regression coefficients of the models were assessed using Design –Expert version 10.0 software. The ANOVA result of optimization for the turbidity removal indicates that the model is significant at 95% confidence level ($p<0.05$). moreover, the dosage and contact time were both significant but the mixing speed is not a significant factor in the optimization of the turbidity removal. Furthermore, AB, AC and A^2 were insignificant while BC gave an important contribution to the turbidity removal.

Statistical analysis outlined a comparative model for the selection and gave significant quadratic model with coefficient of regression r^2 = 0.9847. The lack of fit is not significant when compared to error and this indicate that the model is adequate to describe the data as shown in table 3.3 and 3.4.

Table 3.3: ANOVA Result of Moringa pod

Analysis of variance table						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	172.45	9	19.16	23.54	< 0.0001	Significant
A-Amount of coagulant	23.10	1	23.10	28.38	0.0003	
B-contact time	24.55	1	24.55	30.17	0.0003	
C-Mixing speed	3.76	1	3.76	4.62	0.0572	
AB	0.32	1	0.32	0.39	0.5447	
AC	3.73	1	3.73	4.58	0.0581	
BC	26.43	1	26.43	32.47	0.0002	
A^2	0.42	1	0.42	0.51	0.4899	
B^2	6.65	1	6.65	8.17	0.0170	
C^2	22.42	1	22.42	27.54	0.0004	
Residual	8.14	10	0.81			
Lack of Fit	6.44	5	1.29	3.80	0.0846	not significant
Pure Error	1.70	5	0.34			
Cor Total	180.59	19				

Table 3.4: ANOVA Result of soya bean

Analysis of variance table [Partial sum of squares - Type III]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	92.01	9	10.22	25.86	< 0.0001	significant
A-Amount of coagulant	11.64	1	11.64	29.44	0.0003	
B-Contact time	1.58	1	1.58	4.01	0.0732	
C-Mixing speed	18.01	1	18.01	45.55	< 0.0001	
AB	10.53	1	10.53	26.64	0.0004	
AC	0.90	1	0.90	2.27	0.1628	
BC	3.54	1	3.54	8.95	0.0135	
A^2	5.05	1	5.05	12.78	0.0051	
B^2	4.72	1	4.72	11.93	0.0062	
C^2	21.71	1	21.71	54.90	< 0.0001	
Residual	3.95	10	0.40			
Lack of Fit	2.65	5	0.53	2.03	0.2281	not significant
Pure Error	1.31	5	0.26			
Cor Total	95.96	19				

The plot of RSM interaction effect is shown in figure 3.1 and 3.2 for moringa oleifera pod and soya beans pod respectively. The curvature from the contact time is higher than the amount of coagulant indicating the effect of the contact time on the removal efficiency is higher.

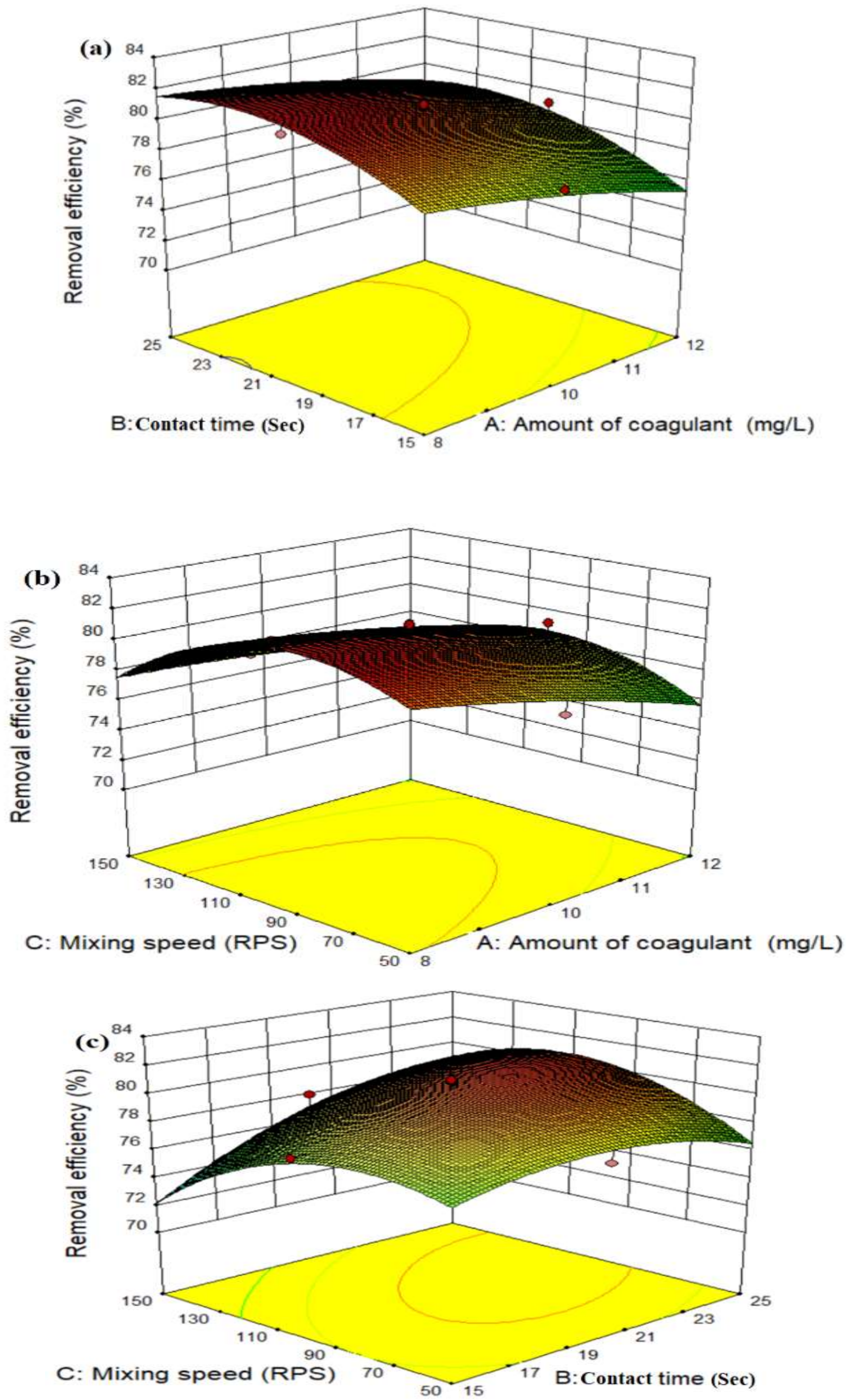

Figure 3.1: 3-D contour of moringa pod

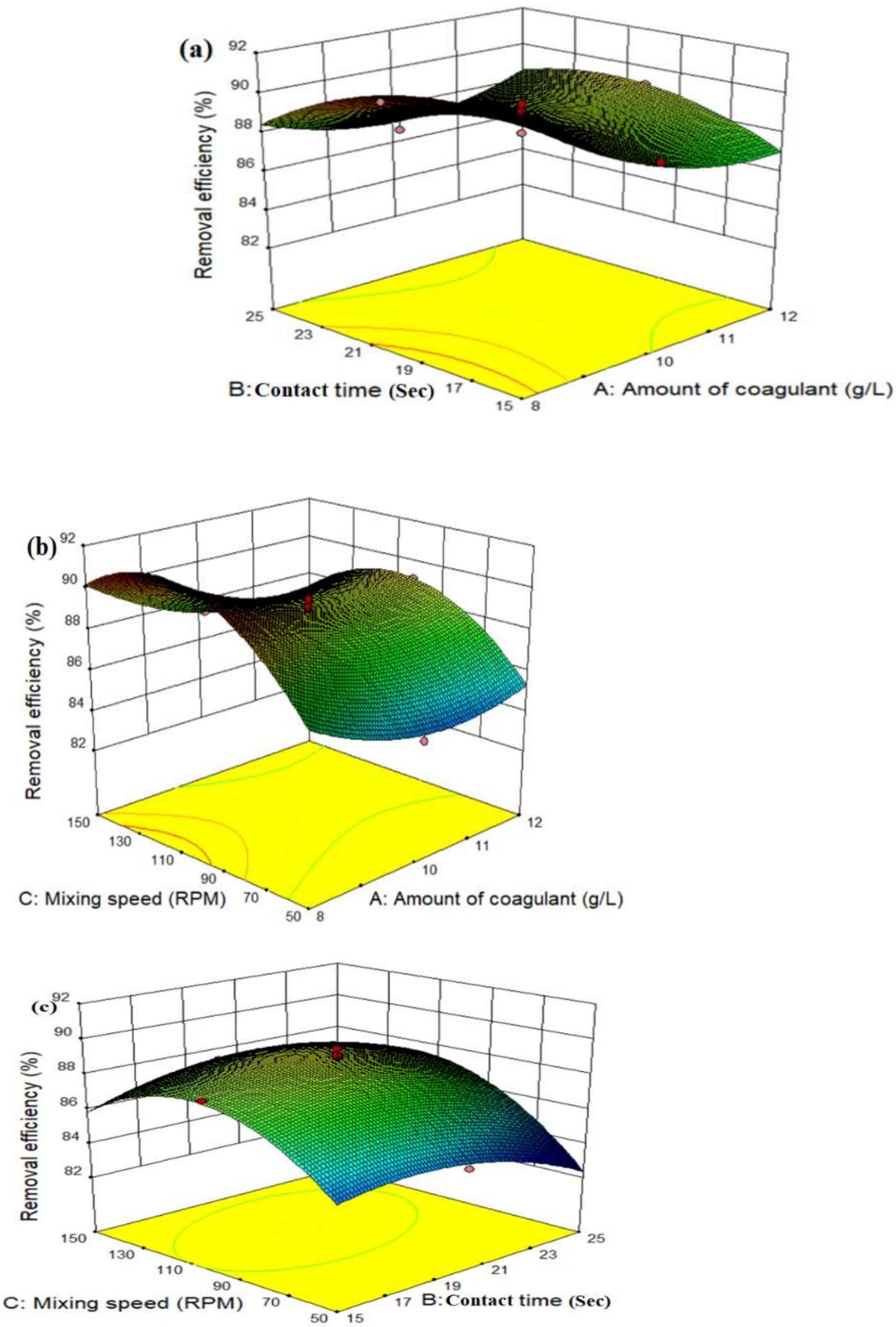

Figure 3.2: 3-D contour of soya beans pod

The interactions in the rest of the response surfaces showed similar patterns with respect to curvatures where one of the variable shows more influence than the other in terms of removal efficiency. Concurrently, the effect of contact time and mixing speed on turbidity removal as shown in figure 3.3c and 3.4c for moringa and soya beans pods respectively showed that both are key factors in high turbidity removal.

Therefore, an increase in mixing speed at lower contact time yielded higher turbidity removal.

3.3 Authentication of predictive model

In this work, the correlation between dosage, contact time and mixing speed was observed using quadratic model and regression coefficient. The significant of these parameters was evaluated using design expert software. It is worthy to note that for a single parameter it shows the effect of that parameter on turbidity removal while for two parameters it represents the interaction of the two parameters and the two parameter show the second order shows their quadratic effects. The positive and negative signs is an indication of combined effect and matches of the terms respectively. This similar to the findings of Olalere *et al* (2016). The regression equation is presented for the turbidity removal in equations 1 and 2 for moringa oleifera and soya beans pods respectively:

Removal efficiency (%) =

$+80.60 - 1.52 * A + 1.57 * B - 0.61 * C + 0.20 * AB + 0.68 * AC + 1.82 * BC - 0.39 * A^2 - 1.55 * B^2 - 2.85 * C^2$ equation (1)

Removal efficiency (%) =

$+88.87 - 1.08 * A - 0.40 * B + 1.34 * C + 1.15 * AB - 0.33 * AC + 0.67 * BC + 1.36 * A^2 - 1.31 * B^2 - 2.81 * C^2$ equation (2)

Where A, B, and C represent the amount of coagulant dosage, contact time and mixing speed respectively and their performance can be predicted using the equations 1 and 2.

The authentication of the model was conducted by replicating the experiment for turbidity removal. Design –expert software using single solution developed the optimal condition and analogy was made between the predicted and the experimental results using the model equation. The highest turbidity removal was selected as optimal condition and this indicates that there exists a correlation between the predicted vales and the experimental values. Best turbidity removal was estimated using equation 3

$$\text{Percentage Error} = \frac{predictive\ value}{exprimental\ value} \times 100 \qquad (3)$$

The best turbidity removal response when pods of moringa oleifera and soya beans was in treating turbidity removal was evaluated using the percentage error. This corroborate with the works of Shan et al (2017) opined that the percentage error should not exceed 10% of 95% confidence level is the best condition for validity. This indicates that there is an insignificant difference between the predicted values and the experimental values and percentage error obtained is 1.568 and -1.928. these percentages are very negligible in comparison to the 10% bottom line of the 95% confidence level.

4.0 Conclusion

Dosage, contact time and mixing speed were investigated on turbidity removal. Result s obtained from ANOVA found a vital quadratic model with 95% confidence level ($p< 0.05$) in the optimization of the turbidity removal. Contact time and mixing speed were both significant parameters while dosage was found to be insignificant in the optimization of turbidity removal using moringa oleifera and soya beans pods. The turbidity of the water at optimal conditions was slightly above recommended value of 5NTU this further attest to the potential of moringa oleifera pod and soya beans pod as coagulant for domestic use.

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