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# Optimization of Process Parameter for Coagulation Process in Water treatment

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***Abstract*—** Polyaluminium silicate chloride (PAlSiC), a hybrid coagulant was synthesized by co-polymerization technique using Aluminium salt and Polysilicic acid at different OH/Al ratio and Al/Si molar ratios. The aim of this paper was to optimize the parameters for the removal of turbidity in coagulation-flocculation process in water treatment using Box Behnken method. Effectiveness of important process parameters Al/Si molar ratio, OH/Al molar ratio, pH and dosage were determined, optimized and modeled successfully. Significant quadratic polynomial models were obtained. Hence, PAlSiC has proven the potentiality for the turbidity removal in low turbid water.

***Keywords*—**Coagulation, Hybrid Coagulant, Optimisation, PAlSiC.

## I. INTRODUCTION

In coagulation process, the hydrolysis of metal ions is an important reaction for the destabilization of suspended particles and organic matter [1].

The hydrolysis process using single nucleus metallic salt (like aluminium) in coagulation was completed in a short time, which make the coagulation hard to control [2],[3]. Usually, the precipitates of metal hydroxide will be produced afterwards.

On the other hand, the degree of hydrolysis of polymeric salts can be controlled during manufacture; therefore the complicated reaction caused by the hydrolysis of metal salt in coagulation can be reduced. Consequently, the use of the polymeric salts provides a simpler and more precise way to control the reaction in coagulation [4]-[7].

However, polymeric coagulants like PAC are not effective in neutralizing the surface charges of particles in low-turbidity water, thus failing to form the settleable flocs [8]. Its molecular weight and size for aggregating action and its stability to resist further hydrolysis are still much lower than those of organic polymers.

Recently, it was reported that under certain conditions activated silica, a polysilicic acid could be combined with polymeric substances to form a new type of inorganic polymer coagulant, having larger particle size and better turbidity removal efficiency [9],[10].

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The turbidity removal efficiency depends on many factors like pH, dosage etc., therefore the optimization of factors are very important.

The classical optimization technique of changing one variable at a time to study the effects of variables on the response is time consuming and expensive. Statistical design of experiments is a useful technique for obtaining valuable and statistically significant models of phenomenon by performing minimum number of experiments.

Response surface methodology (RSM) is used for modeling and analysis of problems in which response of interest is influenced by several variables, with the objective of optimizing this response. One of the common designs under RSM is Box Behnken method.

The aim of this study was to determine the optimal condition for removal of turbidity in water treatment. The experimental runs were designed in accordance with Box Behnken method.

## II. MATERIALS AND METHODS

### *A. Preparation of Coagulant and Synthetic Turbid water*

The coagulants were prepared by the procedure given in literature (Gyawali et al). The synthetic turbid water was prepared using kaolin clay.

### *B. Coagulation method*

Coagulation test were performed using jar test apparatus. The initial turbidity of water sample was 11.3 NTU. The experiment was run in accordance with Box Behnken method. Percentage removal of turbidity was calculated by using the following formula,

Percentage removal $=(T_2-T_1)/ T_1 *100$

Where, $T_1$ –Initial turbidity & $T_2$ –Final turbidity

### *C. Experimental design and Statistical analysis*

Design expert software was used for design, mathematical modeling and optimization. The independent variables used in this study were Al/Si molar ratio (A), OH/Al molar ratio (B), pH (C) and dosage (D) each with three levels. Turbidity removal efficiency (y) was taken as dependent variable. The four independent variables were converted into dimensionless ones. According to Box Behnken design 29 experiments were conducted.

## III. RESULTS AND DISCUSSION

*Box Behnken and Response Surface Methodology* were employed in order to illustrate the nature of response surface in the experimental design. *Table 1* shows the experimental runs carried out and *Table 2* shows the levels of each variable.

ANOVA was used for analyses of the data. The quality of fit polynomial model was expressed by the coefficient of determination $R^2$ and its statistical significance was checked by F test.

TABLE I
EXPERIMENTAL RUN

| Run no | Al/Si | OH/Al | pH | Dosage (mg/l) |
|---|---|---|---|---|
| 1 | 5 | 1.5 | 7 | 2 |
| 2 | 15 | 1.5 | 7 | 2 |
| 3 | 5 | 2.5 | 7 | 2 |
| 4 | 15 | 2.5 | 7 | 2 |
| 5 | 10 | 2 | 5 | 1 |
| 6 | 10 | 2 | 9 | 1 |
| 7 | 10 | 2 | 5 | 3 |
| 8 | 10 | 2 | 9 | 3 |
| 9 | 5 | 2 | 7 | 1 |
| 10 | 15 | 2 | 7 | 1 |
| 11 | 5 | 2 | 7 | 3 |
| 12 | 15 | 2 | 7 | 3 |
| 13 | 10 | 1.5 | 5 | 2 |
| 14 | 10 | 2.5 | 5 | 2 |
| 15 | 10 | 1.5 | 9 | 2 |
| 16 | 10 | 2.5 | 9 | 2 |
| 17 | 5 | 2 | 5 | 2 |
| 18 | 15 | 2 | 5 | 2 |
| 19 | 5 | 2 | 9 | 2 |
| 20 | 15 | 2 | 9 | 2 |
| 21 | 10 | 1.5 | 7 | 1 |
| 22 | 10 | 2.5 | 7 | 1 |
| 23 | 10 | 1.5 | 7 | 3 |
| 24 | 10 | 2.5 | 7 | 3 |
| 25 | 10 | 2 | 7 | 2 |
| 26 | 10 | 2 | 7 | 2 |
| 27 | 10 | 2 | 7 | 2 |
| 28 | 10 | 2 | 7 | 2 |
| 29 | 10 | 2 | 7 | 2 |

TABLE II
LEVELS OF FACTOR

| Factor | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| A | 5 | 10 | 15 |
| B | 1.5 | 2 | 2.5 |
| C | 5 | 7 | 9 |
| D | 1 mg/l | 2 mg/l | 3 mg/l |

Model terms were evaluated by the P value with 95% confidence level. Three dimensional plots and their respective contour plots were obtained based on the effects of four factors at three levels. Equation (1) presents the models for turbidity removal efficiency (%).The quadratic model statistical results for turbidity removal were summarized as follows:

| | |
|---|---|
| Std. Dev. | 1.28 |
| Mean | 84.65 |
| R-Squared | 0.9831 |
| Adj R-Squared | 0.9662 |
| Pred R-Squared | 0.9027 |
| C.V. % | 1.52 |
| PRESS | 132.97 |
| Adeq Precision | 27.133 |

The Model F-value of 58.23 implies the model is significant for turbidity removal. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, D, $A^2$, $C^2$ are significant model terms.

Turbidity removal efficiency(%)= -71.24 + 1.23 A + 9.018 B + 39.209 C + 6.657 D – 0.36AB – 1.50000E-0.003 AC - 0.13 AD – 0.20 BC - 0.49 BD + 0.22 CD – 0.060950 $A^2$ + 0.50000 $B^2$ – 2.81625$C^2$ – 0.74375 $D^2$ **(1)**

They show a high reliability in the estimation of turbidity removal efficiency. A high $R^2$ value ensures a satisfactory adjustment of the quadratic model to the experimental data. In optimizing a response surface, an adequate fit of model should be achieved to keep away from poor outcome. It also demonstrate that response surface quadratic model for our parameter were significant at the 5% confidence level since P value was less than 0.05.

The "Pred R-Squared" of 0.9027 is in reasonable agreement with the "Adj R-Squared" of 0.9662. "Adeq Precision" measures the signal to noise ratio and was found to be 27.133 which indicates an adequate signal. A ratio greater than 4 is desirable.This model can be used to navigate the design space.

*A. Three dimensional plots:*

The response surface plots obtained form the software provide a three dimensional view of the turbidity removal efficiency with different combination of independent variable. Some of the interaction effect were shown in Figure 1.

*B. Optimization and validation experiment:*

Optimized condition under specified constraints were obtained for highest desirability at Al/Si molar ratio 6.39 , OH/Al molar ratio 2.47, pH 6.85 and dosage 3. Under this condition, 98.44% turbidity removal was predicted based on desirability function of 1.00. In order to confirm the accuracy of the predicted model and reliability of optimum combination, an additional experiment was carried out at optimum condition. The experimental value 99.1% was found to agree well with predicted 98.44%. The low error in the experimental and predicted value indicates good agreement of the results achieved from models and experiments. These results confirm that RSM is a powerful tool for optimizing the operational condition for turbidity removal in coagulation process.

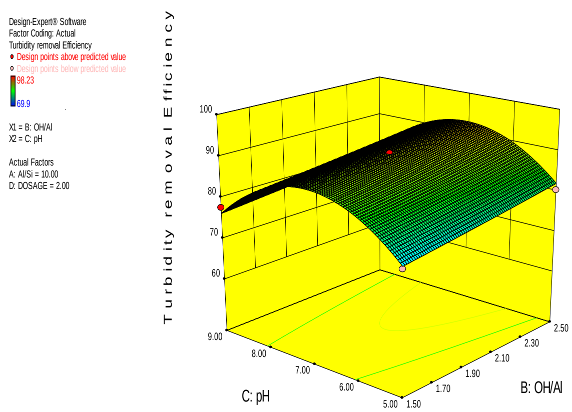


Fig. 1(A) Interaction between pH and OH/Al

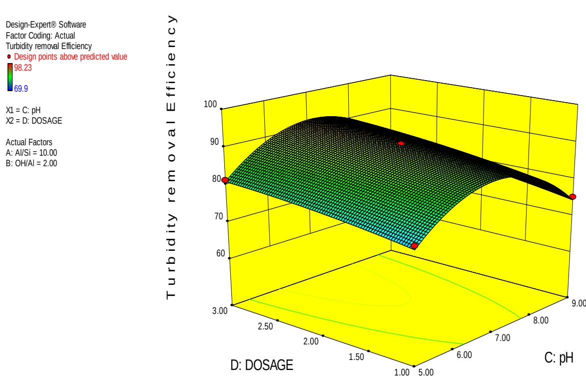


Fig. 1(B) Interaction between pH and Dosage

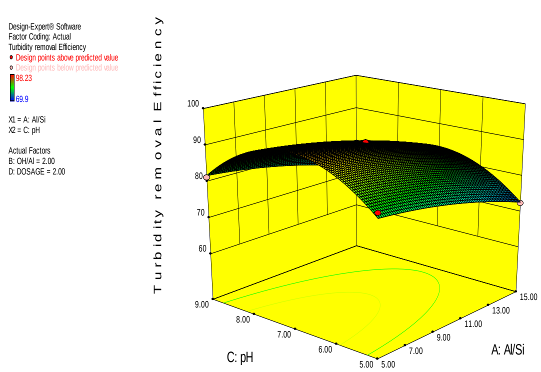


Fig. 1(C) Interaction between pH and Al/OH

## IV. CONCLUSION

Box Behnken design and response surface methodology were adopted in this study to determine the optimal experimental condition for turbidity removal. Optimum conditions were found to be Al/Si molar ratio 6.39 , OH/Al molar ratio 2.47, pH 6.85 and dosage 3. Agreement of the quadratic model with the experimental data was satisfactory. Hence PAlSiC can be the potential coagulant for the water treatment.

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