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Formulation of Clog Removal by Using Mixture Design

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Abstract: Liquid for clog removal is one of the detergent products sold in the market. Generally, the formulation with good performance in term of cleaning effectiveness is desirable. On the other hand, the stability and cost of the product also must be considered. The quality of the clog removal is directly linked to the basic ingredients used in formulation. In this research, various compositions of sodium hypochlorite, sodium hydroxide, sodium carbonate and sodium meta-silicate were used to optimise the clog removal formulation. Twenty combination components were selected according to the D-optimal criterion. The cost and physical properties of the clog removal such as pH, cleaning effectiveness and stability were studied. Contour graphics were generated to assess the change in the response surface in order to understand the effect of the mixture composition on clog removal characteristics. The statistical study shows that the fitted model was adequate to describe the responses.

Key words: Clog removal formulation, D-Optimal, mixture design

INTRODUCTION

Demand of detergent is increasing with population growth. In Malaysia, more than 100,000 tons of detergent has been sold in the market and it is expected to reach 5.9 million tons in every year. There are several types of detergents such as shampoo, soap for body care, dish wash and liquid cleaner (Elvers and Hawkins, 1995).

Clog removal is one of the functions of detergent products sold in the market. Clog removal formula commonly used in pipeline system to keep it free from break sewage, solid waste, fat, keratin, starch and paper. Domestic waste such as fat, oil and grease always tend to form a thin sticky layer on the pipe wall. Other waste material will accumulate on the top of this material and being a medium of bacteria growth, tend to cause clogged in the pipe system (Awang *et al*., 2002).

The problem faced in the clog removal development is to achieve the optimum performance, with good appearance and stability at minimum cost. In formulation work, statistical experimental design such as D-optimal mixture design is useful to obtain a product with the required characteristics (Awang *et al*., 2004). The primary goal of designing an experiment statistically is to obtain valid results at minimum effort, time and resources (Myers and Montgomery, 2002).

In this study, sodium hypochlorite, sodium hydroxide, sodium meta-silicate and sodium bicarbonate have been used to produce clog removal formulations (Buhri *et al*., 2003). The formulations were based on the composition obtained by D-optimal mixture design. The cost and physical properties of the clog removal such as pH, effectiveness and stability were studied. Contour graphics were generated to assess the change in the response surface in order to understand the relationship between the mixture composition, physical properties and cost of the clog removal formulation.

MATERIALS AND METHODS

Design of experiment and clog removal formulation: The experimental settings were performed by mixture experimental design. The experimental design of four-components system was conducted by using Design Expert, version 6.10, Stat-Easy Inc., Minneapolis, USA. A set of candidate points in the design space was selected using the D-optimal criterion (Myers and Montgomery, 2002). In this study, there are constraints on the component proportions X_j that take the form of lower L_j and upper U_j. The constraints of the component proportion are shown in Table 1.

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Table 1: Constraint of the component proportion

Mixture component, X_j	Lower limit, L_j (%)	Upper limit, U_j (%)
Sodium hypochlorite, X_1	2	4.0
Sodium hydroxide, X_2	6	8.0
Sodium meta silicate, X_3	0	0.2
Sodium carbonate, X_4	0	0.5

In this study, twenty clog removal formulations have been prepared in laboratory scale according to the composition obtained by the mixture design. The ingredients used in clog removal formulations were sodium hypochlorite, sodium hydroxide, sodium meta-silicate and sodium bicarbonate. These components were added together in a 250 mL vessel started by water and followed by sodium hydroxide, sodium meta-silicate, sodium carbonate and sodium hydroxide. The mixture was then homogenised by using magnetic stirrer at the lowest speed. The clog removal produced was stored for 24 h before being tested for physical characteristics.

Characterization of clog removal physical properties: The clog removal pH was determined by using pH meter. Meanwhile, the effectiveness of the clog removal formulation was estimated by measuring the solubility of keratin in clog removal formulation. A three cm length of keratin was dissolved into 25 mL of clog removal solution (Awang *et al*., 2004). The time for keratin to fully dissolve were taken for each formulation.

RESULTS AND DISCUSSION

Relationship between composition variation and the pH value of the clog removal: Figure 1 shows the three-dimensional response surface plot of the pH. NaOH composition was kept constant since this component has the less effect on the pH. Based on the contour plot, the pH of the clog removal increase with an increase in the $Na_2Si_3O_7$ and NaOCl composition, whereas the pH of the clog removal reduced with the increases in Na_2CO_3 composition.

Relationship between composition variation and the effectiveness of the clog removal: The effectiveness of the clog removal was estimated by measuring the solubility of keratin in clog removal formulation. The three-dimensional response surface plot of the time rate is shown in Fig. 2. $Na_2Si_3O_7$ composition was kept constant since this component has the less effect on the keratin solubility. As shown in Fig. 2, the time rate of the clog removal increases with an increase in the NaOH composition, which means that the effectiveness of the clog removal reduced with higher amount of NaOH. On the other hand, the time rate of the clog removal reduced

Table 2: Optimisation target for the response

Response	Goal
Cost	Minimum
pH	In range of 8-13
Time rate	Minimum
Energy consumption	Minimum

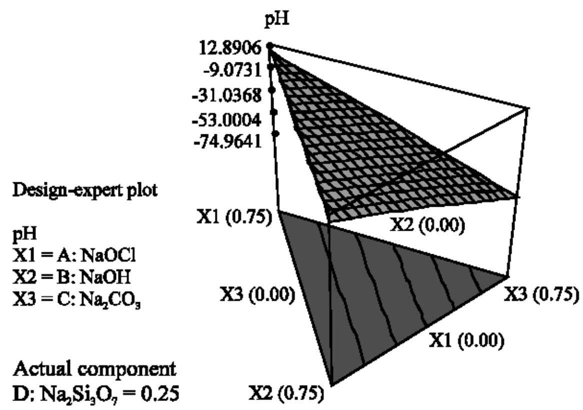

Fig. 1: Three-Dimensional surface of pH response

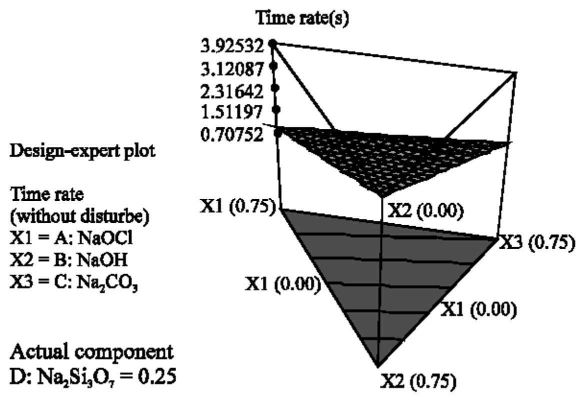

Fig. 2: Three-Dimensional surface of time rate response

with the increase of NaOCl and Na_2CO_3 composition. An increase in NaOCl and Na_2CO_3 amount enhance the effectiveness of the clog removal.

Optimisation of clog removal formulation: Numerical optimisation was performed in order to obtain the formulation with desired characteristics. The goal for each response is shown in Table 2.

The result of the optimisation method suggests that the optimum formulation consists of 3.53% NaOCl, 7.17% NaOH, 0.00 % Na_2CO_3, 0.00% $Na_2Si_3O_7$ and 89.3% water.

CONCLUSIONS

Twenty clog removal formulations have been prepared. The effects of NaOCl, NaOH, Na_2CO_3 and $Na_2Si_3O_7$ compositions on physical properties and effectiveness of the clog removal formulation have been studied. The results indicate that the physical properties and effectiveness can be manipulated by changing the mixture composition. Numerical optimisation has been conducted and found that the most optimum formulation consists of 3.53% NaOCl, 7.17% NaOH, 0.00 % Na_2CO_3, 0.00% $Na_2Si_3O_7$ and 89.3% water.

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