Performance of combined persulfate/aluminum sulfate for landfill leachate treatment

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A B S T R A C T

Although landfilling is still the most suitable method for solid waste disposal, generation of large quantity of leachate is still considered as one of the main environmental problem. Efficient treatment of leachate is required prior to final discharge. Persulfate ($S_2O_8^{2-}$) recently used for leachate oxidation, the oxidation potential of persulfate can be improved by activate and initiate sulfate radical. The current data aimed to evaluate the performance of utilizing Al$_2$SO$_4$ reagent for activation of persulfate to treat landfill leachate. The data on chemical oxygen demand (COD), color, and NH$_3$–N removals at different setting of the persulfate, Al$_2$SO$_4$ dosages, pH, and reaction time were collected using a central composite design (CCD) were measured to identify the optimum operating conditions. A total of 30 experiments were performed, the optimum conditions for $S_2O_8^{2-}$/Al$_2$SO$_4$ oxidation process was obtained. Quadratic models for chemical oxygen demand (COD), color, and NH$_3$–N removals were significant with p-value < 0.0001. The experimental results were in agreement with the optimum results for COD and NH$_3$–N removal rates to be 67%, 81%, and 48%, respectively. The results obtained in leachate treatment were compared with those from other treatment processes, such as $S_2O_8^{2-}$ only and Al$_2$SO$_4$ only, to evaluate its
effectiveness. The combined method (i.e., S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−}/Al\textsubscript{2}SO\textsubscript{4}) showed higher removal efficiency for COD, color, and NH\textsubscript{3}–N compared with other studied applications.

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Specifications Table

| Subject area            | Environmental Engineering                  |
|-------------------------|--------------------------------------------|
| More specific subject area | Landfill leachate treatment                |
| Type of data            | Equations and statistical data             |
| How data was acquired   | All experiments performed in 250 mL glass conical flasks orbital shaker unit, Aluminium sulphate (ZnSO\textsubscript{4}) was used to initiate sulphate radicals from persulfate (Na\textsubscript{2}S\textsubscript{2}O\textsubscript{8}) and improve the oxidation potential. The concentration of COD, color, and ammonia was measured before and after each run and the removal efficiencies were calculated. |
| Data format             | Table, Figure, Equation                    |
| Experimental factor     | Monitoring the removal efficiencies of COD, colour, COD, and ammonia from leachate. |
| Experimental features   | Response surface methodology (RSM) was used to design the experimental conditions for treatment of leachate using simultaneous persulfate/ZnSO\textsubscript{4} oxidation. Removal efficiency of COD, colour, and ammonia was measured. The relationship between experimental factors (S\textsubscript{2}O\textsubscript{8}/Al\textsubscript{2}SO\textsubscript{4} ratio dosage, pH and reaction time) and responses (COD, colour, COD, and ammonia) was evaluated. |
| Data source location    | Malaysian Institute of chemical & Bioengineering Technology |
| Data accessibility      | Universiti Kuala Lumpur, (UniKL, MICET), 78000, Melaka, Malaysia. |

Value of the data

- This article presents data on the performance of utilize Al\textsubscript{2}SO\textsubscript{4} to activate persulfate for leachate treatment.
- The data provides comparison of the treatment efficiencies between persulfate alone, Al\textsubscript{2}SO\textsubscript{4} alone and combined persulfate/Al\textsubscript{2}SO\textsubscript{4}.
- The data show the relationship between experimental factors and the responses statistically using mathematical models for COD colour and ammonia.
- The optimum results can be useful for wide application on wastewater treatment.

1. Data

The data for general characteristics of landfill leachate used in this study are presented in (Table 1). Furthermore, the data in this article covers the performance of combined persulfate/aluminum sulfate for leachate treatment based on three measured responses COD, color, and NH\textsubscript{3}–H removals at different setting of the persulfate, Al\textsubscript{2}SO\textsubscript{4} dosages, pH, and reaction time (Table 2). The data for COD, color, and NH\textsubscript{3} removals obtained from faced central composite design (FCCD) are presented in Table 3. The significance of the influential variables are presented in Table 4 (analysis of variance...
Table 1
Characteristics of Sungai Udang landfill leachate.

| Parameters               | Value |
|--------------------------|-------|
| COD (mg/L)               | 2300  |
| BOD (mg/L)               | 110   |
| NH₃–N (mg/L)             | 870   |
| Color (PT Co.)           | 4800  |
| pH                       | 8.6   |
| Suspended solids (mg/L)  | 88    |
| Conductivity, (μS/cm)    | 18,940|

*Average of two samples taken from March and June 2017.

Table 2
Independent variables (factors) and corresponding levels used for optimization.

| Variables               | Symbol | Range and levels |
|-------------------------|--------|------------------|
|                         |        | Low level (−1)   | Center (0) | High level + 1 |
| Persulfate dosage       | X₁     | 1 ml             | 5.5 ml     | 10 ml          |
| Al₂(SO₄)₃ dosage        | X₂     | 1 ml             | 5.5 ml     | 10 ml          |
| pH                      | X₃     | 3                | 6          | 9              |
| Reaction time           | X₄     | 30               | 105        | 180            |

(ANOVA)). Mathematical models that show the effect of significant variables on COD, color, and NH₃–N removals are presented in Eqs. (1)–(3) respectively. Fig. 1 shows the predicted and actual standardized residual for COD, color and NH₃–N, removal. Fig. 2, presents the two-factor interaction plot for the behavior of combined Al₂SO₄ and persulfate on COD color and NH₃–N removal. Fig. 3. Shows the three-dimensional response surface for the effect of combined Al₂SO₄ and persulfate on COD color and NH₃–N removal. Fig. 4, compared the treatment efficiency between the three related treatment processes; persulfate, Al₂SO₄ and combined persulfate/Al₂SO₄ for COD, color and NH₃–N removal.

The second-order polynomial model for COD, color, and NH₃–N removals are given in Eqs. (1)–(3), respectively.

\[
\text{COD} = 53.88 - 2.17X₁ - 0.30X₂ - 1.71X₃ - 2.33X₄ + 14.27X₁X₂ - 9.04X₂X₃ - 12.64X₃X₄ - 0.68X₄ + 4.08X₁X₂ - 3.26X₁X₃ - 3.09X₁X₄ - 1.06X₂X₃ - 0.59X₂X₄ + 2.79X₃X₄
\]

\[
\text{Color} = 71.37 + 0.69X₁ + 2.93X₂ - 0.45X₃ + 3.28X₄ - 0.40X₁X₂ - 9.77X₂X₃ + 6.22X₃X₄ + 3.22X₄ + 0.76X₁X₂ - 1.80X₁X₃ - 1.83X₁X₄ - 2.66X₂X₃ - 1.02X₂X₄ - 0.17X₃X₄
\]

\[
\text{NH₃–N} = 34.60 - 0.33X₁ - 1.04X₂ - 2.81X₃ - 3.92X₄ + 8.47X₁X₂ - 5.78X₂X₃ - 2.31X₃X₄ - 8.62X₄ + 1.62X₁X₂ - 1.81X₁X₃ - 2.71X₁X₄ - 1.46X₂X₃ - 1.18X₂X₄ + 2.83X₃X₄
\]

where \(Y₁\), \(Y₂\), and \(Y₃\) represent the COD removal, Color removal and ammonia (NH₃), respectively.

2. Experimental design, materials and methods

2.1. Leachate Sampling and Characteristics

Leachate samples were collected from the detention pond at Sungai Udang Landfill Site (SULS), Melaka, Malaysia. SULS has an area of 7 ha, receiving approximately 1200 t of municipal
solid waste daily and start receiving waste at 1st of April 2015. In this study, the leachate samples were collected 6 times manually from February 2017 to Jun 2017 using 2 L plastic containers. The collected samples were immediately transported to the laboratory, characterized, and stored in cool room to 4°C. The general characteristics of the leachate used in the study are presented in Table 1. All samples were collected, preserved and analysed by following Standard Methods for the Examination of Water and Wastewater [1].

2.2. Experimental Procedures

In the current study, Sodium persulfate (Na$_2$S$_2$O$_8$ M = 238 g/mol) and Aluminum sulfate (Al$_2$SO$_4$ 342.15 g/mol) were used for advanced oxidation during the oxidation of leachate samples. Several dosages of S$_2$O$_8$ and Al$_2$SO$_4$ were gradually mixed with 100 mL of leachate samples to determine the optimum S$_2$O$_8^{2-}$ and Al$_2$SO$_4$ dosage according to the efficiencies of COD, Color and NH$_3$–N removal. Orbital Shaker (Luckham R100/TW Rotatable Shaker 340 mm × 245 mm) with at 200 rpm was used for samples shaking [2]. All experiments were performed at room temperature (28 0 C) using 100 mL leachate samples in conical flasks with a 250 mL capacity. pH of the samples was controlled by using 3 M sulphuric acid solution and 3 M sodium hydroxide solution [3]. All experiments were performed at laboratory of Malaysian Institute of Chemical & Bioengineering Technology, University of Kuala Lumpur, Melaka, Malaysia.

### Table 3

The results of FFCD including coded and actual variable with the results of three responses (Color, COD, NH$_3$ removals).

| Coded variable | Actual variable | Responses |
|---------------|-----------------|-----------|
| Al$_2$SO$_4$  | Persulfate pH RT | Color removal COD removal NH-N removal |
| −1 0 0 0 | 1 5.5 6 105 | 69 67.3 47.8 |
| 0 0 0 0 | 5.5 5.5 6 105 | 69.53 51.4 35.6 |
| −1 1 −1 −1 | 5 10 3 30 | 70.6 47.9 34.33 |
| −1 −1 1 −1 | 1 1 9 30 | 64.24 54.5 31.2 |
| 0 −1 0 0 | 5.5 1 6 105 | 56.8 39.78 31.07 |
| 0 0 −1 −1 | 5.5 5.5 6 30 | 72.24 55.6 26.78 |
| 1 1 −1 −1 | 10 10 3 30 | 77.53 61.6 44.33 |
| 1 −1 −1 −1 | 10 1 3 30 | 63.31 50.9 42.22 |
| 0 0 1 1 | 5.5 5.5 6 180 | 77.87 48.8 25.4 |
| 1 0 0 0 | 10 5.5 6 105 | 73.67 67 38.56 |
| −1 −1 −1 −1 | 1 1 3 180 | 71 50.7 28.67 |
| −1 1 1 1 | 1 10 9 180 | 75.54 47.5 19.33 |
| −1 1 −1 −1 | 1 10 3 180 | 74.67 38.5 21.2 |
| −1 −1 1 1 | 10 1 9 180 | 68.45 31.7 19.73 |
| 0 1 0 0 | 5.5 10 6 105 | 67.34 47.89 26.78 |
| 1 1 −1 1 | 10 10 3 180 | 81.66 40.92 20.53 |
| −1 1 1 1 | 10 10 9 180 | 70.27 42.2 18.76 |
| −1 1 1 −1 | 1 10 9 30 | 67.02 39.7 19.67 |
| 0 0 0 0 | 5.5 5.5 6 105 | 69.53 56.76 35.57 |
| 0 0 1 0 | 5.5 5.5 9 105 | 75.89 33.67 32.47 |
| 0 0 −1 0 | 5.5 5.5 3 105 | 80.22 46.8 32.33 |
| 1 1 1 −1 | 10 10 9 30 | 68.45 42.2 25.53 |
| 0 0 0 0 | 5.5 5.5 6 105 | 69.23 55.37 35.56 |
| −1 −1 −1 −1 | 1 1 3 30 | 57.83 47.6 25.87 |
| 1 −1 1 −1 | 10 1 9 30 | 68.98 40.4 22.33 |
| 0 0 0 0 | 5.5 5.5 6 105 | 69.53 57.32 35.55 |
| 0 0 0 0 | 5.5 5.5 6 105 | 74.98 56.8 35.45 |
| −1 −1 1 1 | 1 1 1 9 180 | 79.78 60.2 28.93 |
| 0 0 0 0 | 5.5 5.5 6 105 | 72.62 51.6 29.23 |
2.3. Experimental design

The effect of four factors, namely persulfate dosage ($X_1$), Al$_2$SO$_4$ dosage ($X_2$), pH ($X_3$) and reaction time ($X_4$) on three responses COD ($Y_1$), color ($Y_2$) and ammonia ($Y_3$) removal efficiencies from leachate was studied. The relationship between the factors and the three responses was modelled and optimized by using face centred composite design (FCCD). FCCD is one of the frequently used design in response surface methodology (RSM) to model and optimize the relationship between the input factors and the output responses. The levels of selected factors were chosen based on literature and preliminary experiments, the actual and coded levels are given in Table 2.

The relationship between the selected factors ($X_1$, $X_2$, $X_3$, $X_4$) and each of the responses ($Y_1$, $Y_2$, $Y_3$) is usually described in response surface methodology (RSM) by a second-order polynomial as given in Eq. (4).

$$Y = \beta_0 + \sum_{i=1}^{4} \beta_i X_i + \sum_{i}^{4} \beta_i X_i^2 + \sum_{i<j} \beta_{ij} X_i X_j$$

Fig. 1. Design expert plot; predicted and actual standardized residual for (A) COD, (B) color (C) NH$_3$–N, removal.
where $Y$ represents the dependent variable, $\beta_0, \beta_i$ and $\beta_{ij}$ are linear coefficient, quadratic coefficient and interaction coefficients respectively, need to be estimated, and $X_i$ represents the independent variables.

Thirty runs are required for FCCD to cover all possible combination of $X_1, X_2, X_3,$ and $X_4$ distributed as follows: sixteen runs for the factorial design, eight runs are for axial (star) points and six runs at the center of the design [4,5]. To avoid or minimize the effect of unexpected variability in the responses, thee experiments were run in random order. The data for the thirty-run of FCCD with the coded and actual levels of the four factors are given in Table 3.

2.4. Analytical methods

COD, color and NH$_3$–N, were immediately tested before and after each experiment. Leachate sample was shacked well analyzed. NH$_3$–N concentration was measured by the Phenol Method No. (4500) using a UV–vis spectrophotometer at 640 nm with a light path of 1 cm or greater. pH was measured using a portable digital pH/Mv meter. COD concentration was determined by the open

Fig. 2. Two-factor interaction plot showing the behavior of Al$_2$SO$_4$ and persulfate (■ = 1, ▲ = 10 mL) on (A) COD color (B) and (C) NH$_3$–N removal at 6 pH and 105 min reaction time.
**Fig. 3.** Three-dimensional response surface showing the effect of persulfate/Al₂SO₄ on (A) COD (B) color (C) and NH₃–N removal at 5.5 ml of persulfate and 105 min reaction time.

**Fig. 4.** Comparison the performance of persulfate, Al₂SO₄ and combined persulfate/Al₂SO₄ for COD, color and NH₃–N removal.
reflux method No. (5220). The test values are presented as the average of the three measurements, and the difference between the measurements of each value was less than 3%. The removal efficiencies of COD and NH₃–N were obtained using the following Eq. (5):

\[
\text{Removal(\%)} = \left(\frac{C_i - C_f}{C_i}\right) \times 100
\]

(5)

where \( C_i \) and \( C_f \) refer to the initial and final COD and NH₃–N concentrations respectively.

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Transparency document. Supporting information

Transparency data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.05.111.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.05.111.

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