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Optimization of bioreactor performance for the oxidation of ferrous sulfate using Taguchi approach

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Extended abstract

The biological oxidation of ferrous to ferric ion by iron oxidizing bacteria is potentially a useful industrial process for the removal of H_2S from industrial gases, desulphurization of coal, and removal of sulfur dioxide from flue gas. In the bioprocess of H_2S removal an aqueous $Fe_2(SO_4)_3$ solution is used as an absorbent. H_2S is absorbed and oxidized to elemental sulfur. At the same time, Fe^{3+} is reduced to Fe^{2+} according to the following reaction [1]:

$$H_2S + Fe_2(SO_4)_3 \rightarrow S^0 \downarrow +2FeSO_4 + H_2SO_4 \quad (1)$$

Therefore this paper investigates the parameters that influence biooxidation rate of ferrous iron using a native *Sulfobacillus* species, in a packed-bed bioreactor, and the main objective was using Taguchi approach to find a combination of parameters to achieve high biological oxidation rate of ferrous ion. The details of experimental work including microorganism and medium, apparatus and experimental procedure (Bioreactor, biofilm formation on support and operation of the bioreactor) and analysis are described in previous works [2,3].

As table 1 represents, five control factors including temperature, initial pH of feed solution, dilution rate, initial Fe^{+3} concentration and rate of aeration in four levels are considered in Taguchi method. For Taguchi design the commercial software, namely Qualitek-4 (version 4.82.0), was used. L16 orthogonal array has been used to determine the signal to noise (S/N) ratio. It means that 16 experiments with different combinations of the factors suggested by the software have been conducted in order to study the main effects and interactions.

Analysis of variance (ANOVA) was used to determine the optimum conditions and most significant process parameters affecting the concentration of ferric ion. Its objective is to extract from the results how much variations each factor causes relative to the total variation observed in the result.

The level average response analysis can be based upon the S/N data. The analysis is based on the average of S/N data at each level of each factor. The response table of

S/N ratios for control factors is displayed in Table 2. The maximum values correspond to the optimum condition.

Table 1: Factors and their levels for the experiments

Factor	Level 1	Level 2	Level 3	Level 4
A: Temperature (°C)	50	55	60	65
B: Initial pH	1	1.5	2	2.5
C: Dilution rate (1/hr)	0.1	0.2	0.3	0.4
D: Initial Fe^{+3} Concentration (g/L)	1	3	5	7
E: Aeration rate (mL/min)	100	150	200	250

Table 2: Average effect response for signal-to-noise ratios

Factor	A: Temperature (°C)	B: Initial pH	C: Dilution rate (1/hr)	D: Initial Fe^{+3} Concentration (g/L)	E: Aeration rate (mL/min)
Level 1	15.543	14.439	15.152	15.779	15.557
Level 2	15.848	15.38	15.271	15.882	15.514
Level 3	15.601	16.687	15.601	15.465	15.157
Level 4	14.522	15.009	15.49	14.388	15.287
Maximum-Minimum	1.326	2.248	0.449	1.494	0.4
Rank	3	1	4	2	5

The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental conclusions. The confirmation experiment is performed by conducting a test with specific combination of the optimum levels of biooxidation parameters. The confirmation test indicated that the Fe^{+2} biooxidation rate using new design experiments is 8.4 and the 95% confidence intervals for S/N ratio are 17.881±0.639.

Conclusion

Analysis of S/N ratio has been successfully applied for finding out the relative contribution and the optimum factor level combination for the maximum Fe^{+2} biooxidation rate. It is found that the critical process parameters, according to their relative significance, are initial pH of feed solution, initial Fe^{+3} concentration, temperature, dilution rate and aeration rate, respectively. The maximum biological oxidation rate was obtained by setting temperature 55 °C, initial pH 2, initial Fe^{+3} concentration 3 g/L, dilution rate 0.3 h^{-1} and aeration rate 100 mL/min. It was resulted that the biooxidation rate of ferrous iron was increased by 7.7% at the optimum conditions, which they determined by Taguchi optimization method.

References

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