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Application of artificial neural network for prediction of sulfidogenic fluidized bed reactor performance and optimization for the co-treatment of acid-mine drainage with liquid pharmaceutical waste

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Abstract

Acid mine drainage (AMD) is one of the most troubling water pollution sources in South Africa due to its history and current mining activities. In reality, South Africa's economy is driven mainly by the mining sector's existence; hence it is crucial to abate the impact and find treatment solutions to manage AMD. On the other hand, there is a growing concern about the pharmaceutical compounds abundantly found in South African natural water bodies. Hospitals are found to be significant contributors among diverse sources contributing to pharmaceutical pollutants in the environment. Currently, hospital wastewater is discharged to the municipal sewer, ending up in Wastewater Treatment Plants (WWTPs), decreasing the organic contaminants' biodegradation process in the treatment plant. Subsequently, the direct discharge of the WWTP treated effluent (with untreated pharmaceuticals) to receiving waterbodies raises a concern about the impact of these compounds' persistent presence in the environment. As such, both acidic metal and sulfate-containing water and pharmaceutical-rich wastewater are toxic to the environment, thus need urgent attention. To date, co-treatment of acid mine drainage and municipal wastewater has been investigated with several advantages; however, the potential removal of pharmaceutical compounds through the biological process has not been explored.

This work proposed, developed, and assessed the sulfidogenic fluidized-bed reactor system for co-treatment of acid mine drainage and isolated stream of hospital wastewater. A laboratory-scale sulfate-reducing fluidized bed reactor at a controlled mesophilic condition of ±28˚C examined the biotreatment process of real acid mine drainage and hospital wastewater. In this study, there was no supplement of carbon source during the treatment, but only hospital wastewater (HWW) provided the dissolved organic carbon. The overall removal for the effluent chemical oxygen demand (COD) concentrations and sulfate were 39.5 mg/l and 42 mg/l at a COD/SO_4^{2-} the ratio of 0.68 and hydraulic retention time of 8 h. The overall COD oxidation and sulfate reduction performance achieved an average of 96% and 97%, correspondingly; and recorded the removal efficiencies of 44% naproxen and 55% ibuprofen.

Furthermore, the study evaluated the inhibition kinetics and microbial communities to better understand the diverse species and the reaction mechanisms within the system. The kinetics and

microbiology diversity in the sulfidogenic fluidized-bed bioreactor (at 30°C) for co-treatment of hospital wastewater and metal-containing acidic water were examined. The alkalinity from organic oxidation raised the pH of the effluent from 2.3 to 6.1-8.2. Michaelis-Menten modeling yielded (K_m =7.3 mg/l, V_{max} =0.12 mg/l min^{-1}) in the batch bioreactor treatment using sulfate-reducing bacteria. For COD oxidation, the dissolved sulfide inhibition constant (K_i) was 3.6 mg/l, and the K_i value for H_2S was 9 mg/l. The dominant species in the treatment process belong to the *Proteobacteria* group (especially *Deltaproteobacteria*).

To further explore the co-treatment process, a nanoscale zero valent iron was used to enhance the treatment and monitored through an oxidation-reduction potential (Eh) for 90 days. The removal pathway for the nZVI used co-precipitation, sorption, and reduction. The removal load for Zn and Mn was approximately 198 mg Zn/g Fe and 207 mg Mn/g Fe, correspondingly; achieving sulfate removal efficiency of 94% and organic matter (COD, BOD, DOC), TDN reduced significantly, but ibuprofen and naproxen achieved 31% and 27% removal, respectively. This enriched co-treatment system exhibited a high reducing condition in the reactor, as confirmed by Eh; hence, the nZVI was dosed only a few times in biotreatment duration, demonstrating a cost-effective system. Subsequently, the biological process was run for over 210 days to collect enough data for development of predictive artificial neural network model. The metal concentration removal was more than 99% in effluent for iron and zinc, and precipitated predominantly as FeS, FeS_2 and ZnS. The alkalinity generated by COD oxidation improved the pH of the wastewater considerably when the concentration of feed sulfate was less than 3500 mg/l. At an HRT of 8 h, COD oxidation in the reactor precipitated 1345 mg Fe/l/day, 543 mg Al/l/day and 130 – 170 mg Zn/l/day from acidic wastewater and increased the pH from 2.2 to 6.8, due to the formation of metal sulfide precipitate. The ANN model was successfully developed, and the predicted and actual measured concentrations of the outputs found R-value of 0.97.

To summarize, this research study demonstrated a new application of co-treating AMD with pharmaceutical-rich wastewater using fluidized-bed reactor (FBR). Further to that, the co-treatment was enhanced with nZVI to evaluate the heavy metals that were not adequately removed in prior experiments. Finally, the study developed a performance model which may easily be adopted for process design.